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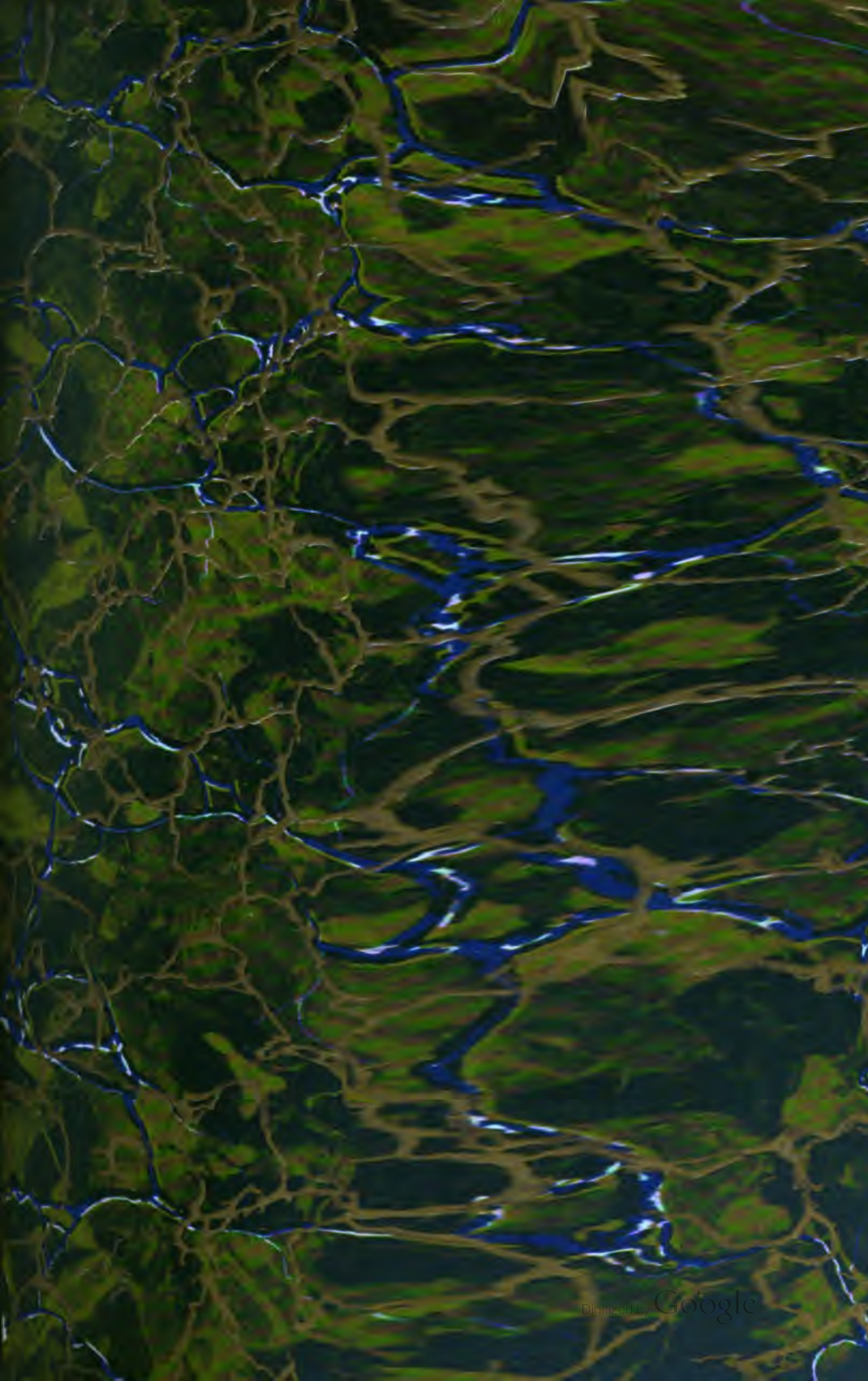

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one select the proper formula, method, or process and in teaching him how and when it should be used.

This volume treats of the constructive details of modern architectural buildings. Besides the artistic elements in building design, the structure must be planned with reference to mechanical considerations. The excavation must be made in an economic and secure manner, the foundations must be properly placed, and the superstructure, whether of wood or masonry, must be properly designed. How this work is laid out and executed is the subject of this volume. The details of joinery, which are the cause of the greatest number of errors in building construction, are explained in a practical manner and fully illustrated. The last part of the volume is intended exclusively for the mechanic. It deals with the steel square, the tool of mystery to many a carpenter, and shows how simple and easy of application it really is.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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EXCAVATING, SHORING, AND PILING

DESCRIPTION OF OPERATIONS

EXCAVATING

LEVELS AND BOUNDARIES

1. Levels.—When preparing a site for the erection of a building, it is of the utmost importance that the elevation of the structure above some imaginary reference line, called a **datum line,** be predetermined. This requirement holds true for all classes of buildings. For instance, railway structures must be erected at such elevations as to facilitate the loading and unloading of cars. Freight houses on a water front must be constructed at such an elevation that during ordinary water level, vessels can easily load or discharge their cargoes; and, all buildings should be built at such elevations that tenants will have easy access to the main floor from the street.

2. The datum line of railway structures, ordinarily, is the elevation of the tracks, which, to a greater or less extent, governs the elevation of the buildings. On the seashore, or on streams affected by tide water, either the mean high tide or the mean low tide is taken as datum. On inland streams subject to freshets and floods, the datum line is generally assumed to be high-water mark.

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3. In most cities, **bench marks** are provided in certain localities. These bench marks consist simply of a mark on the foundation of some enduring structure or on stone monuments partly buried in the earth. The engineering offices of each city keep records of bench marks with their proper elevations, and will describe the location of the marks on request.

4. When laying out the site of a building, a level can be run from the nearest bench mark to the point of excavation. This running of levels, performed usually by an engineer, is a necessary precaution in new sections of a city where the streets have not been graded and paved. By running a level and locating the elevation of the curb, a building can be erected at such an elevation that a subsequent extension of the street to that point will not necessitate a raising or lowering of the structure. Ordinarily, in a city, where the streets are graded and paved, the curb is taken as datum, and the various elevations of a building are measured from the curb line.

5. Buildings that are erected in the country and engineering works that are constructed in isolated places, usually have established an arbitrary datum line depending on the topography of the land. Before work is commenced on the structure, a monument usually is set up to mark the elevation of datum.

6. Boundaries of a Building.—In addition to the elevation of a building, its exact location on a lot, or plot, must also be determined. Too great care cannot be exercised in staking out a building excavation, particularly when the walls are to be carried up close to or on the property line. For this work, it is customary to employ a surveyor to lay out not only the excavation boundaries, but also to stake out the corners of the lot, or plot, of ground.

STAKING OUT EXCAVATIONS

7. If the structure is to be erected in a built-up district, the front of the building probably will be in line with those of the adjacent buildings, and the length of the new building can be measured and marked on the foundation walls of its neighbors. If, on the other hand, the building is to be surrounded by a lawn, or if it is to be set back from the street, it is better practice to lay out the building with an engineer's transit. If a transit cannot be procured, the corners of the lot must be staked out and the boundary lines defined by sighting with the eye, from stake to stake. The distance from the street that it is desired to have the front of the house, is measured off on each side line of the lot from the front corners, and a line is then run across the lot, joining the points last found. The front of the building will be on this line. By measuring from the side lines, the front corners of the building may readily be located.

8. The rear wall of the building is located in the same manner as the front wall, and the side walls can generally be run in without any trouble if the building is rectangular. If the building is not rectangular, it is generally necessary to run more than two lines across the lot, from side to side, before all the corners of the building can be located. Stakes should be driven at each corner, or angle, and by measuring from stake to stake the dimensions of the building can be checked up with the drawings.

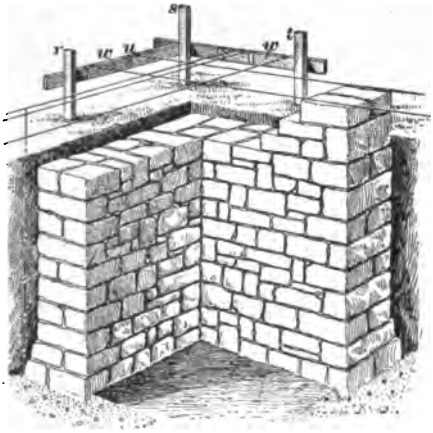


FIG. 1

9. When excavating for a foundation, the stakes driven to mark the location of corners and angles will be disturbed;

therefore, it is customary to set up at each corner of the excavation **line boards**, as shown in Fig. 1. These boards should be set from 6 to 8 feet from the corners, so as to be out of the way as much as possible. The stakes *r*, *s*, and *t* should be from 4 to 5 feet apart, and long enough, when firmly driven into the ground, to allow the cross-pieces *w*, *w* to be nailed to them, having the upper edge level with the top of the foundation wall.

10. All the cross-pieces, or line boards, should be leveled by marking the required level of the top of the foundation, or some other convenient height, on the stakes, then setting the upper edge of each cross-piece even with these marks, and nailing the boards firmly to the stakes.

11. Having **guarded** all the corners by means of line boards, the lines for the excavation may be laid out. These are stretched from corner to corner of the building and fastened to the line boards at each end, as shown at *u*, Fig. 1. The bottom, or footing, courses of the foundation usually extend beyond the line of the wall, consequently the lines that mark the boundary of the excavation are farther out than those that mark the face of the wall.

CHARACTER OF SOIL

12. Before building the foundations for a structure, the ground must be excavated, either for the basement or for trenches, so as to place the masonry below the frost line; but before the excavation is begun, the nature of the soil that is to support the foundation should be determined. If this cannot be determined from existing structures or wells, borings should be made. For this purpose, an auger about 2 inches in diameter and of suitable length is used—similar to an auger for wood boring—and tests made, from 5 to 10 feet apart, over the entire area of the foundation. As the auger brings up samples of the soil, the character of the substrata is determined. When the importance of the proposed structure requires it, trial pits are sometimes dug from 10 to 20 feet apart, especially where a shelving bed of rock or gravel exists at a comparatively short distance below the surface.

13. It is not always safe to rely on the character of the soil in close proximity to the proposed building site, since conditions varying from a bog to a solid granite ledge are often found in the space of a few yards. The soil or strata usually encountered in building operations may be classed under three divisions—*rock*, *virgin soil*, and *made ground.*

14. **Rock,** in its original geological formation, is spoken of as bed rock, or solid ledge. It forms one of the finest foundations for heavy structures, provided that it is of sufficient area for the entire building to rest on. But it is undesirable to have a portion of the foundation rest on a ledge while another portion rests on a softer material, since the building will not settle uniformly and the walls will often crack open at the junction of the ledge and softer material. It often happens that the surface of the rock is uneven and requires considerable blasting and concrete work to secure a good foundation, which adds considerably to the cost. The sandstones and limestones are often found in strata, beds, or layers, one on another; if these layers are not separated by clay, and the beds are even, they make good foundations. The strata, or beds, of rock may shelve, or dip, at varying angles, especially in hilly sections. A ledge is not always reliable, and in many cases will be found to be shaly in structure, partly decomposed, or faulty in other respects.

15. **Virgin soil** is either gravel, clay, loam, sand, or marshy ground in its natural condition.

1. *Gravel*, when compact and united with sharp sand into a firm unyielding stratum, is known as *hard pan.* It makes the best foundation (except bed rock) and, on account of its being more easily leveled, is much less expensive to build on. Usually a 6- or 8-foot stratum of gravel will support any structure, although there may be softer material underneath.

2. *Clay* is the most uncertain of soils, owing to its elasticity, due to being mixed with marl, etc.; to its tendency to

absorb moisture; and, in many cases, to the position of its bed, or strata. In dry seasons it is very firm, while in wet seasons it is elastic and unreliable. When the layers of clay are inclined, the foundation has a tendency to slide, producing results threatening the stability of the superstructure.

3. *Loam*, or clay mixed with sand and other earthy substances, when compact and of considerable depth, is a good material to build on, provided that the structure is not an extremely tall or heavy one.

4. *Sand* is formed from the decomposition of the older rocks, either by the effects of the weather, the action of heavy rains, the wearing away by running water; or the spontaneous decomposition of the rocks themselves. The particles are carried to the rivers and either deposited in their beds or borne out to the ocean. The sand usually found in excavations has its origin either as the formation in the beds of ancient rivers that have long ceased to flow, and is therefore called *river sand*, or by the attrition, or grinding, of the rocks themselves during the geological upheavals in past ages. The latter is called *virgin*, or *pit*, *sand*, and has never known the action of water.

5. *Quicksand* is a very fine sand, often mixed with clay or loamy material in such proportion that it will retain a large quantity of water. By confining quicksand and keeping it as nearly dry as possible, it may be excavated or built on with little more difficulty than common sand. In many cases, quicksands are mixed with a bluish or leaden-colored silt, or soapstone slime. Often in excavating quicksand, beds of this blue marl are found; when wet, it is tough and hard, but when dry, it crumbles to a powder and is utterly unfit for foundations. An attempt to excavate in quicksand without previously getting rid of the water contained therein, is almost as useless as to dig in water itself, for the saturated sand will flow into the excavation as fast as it can be removed.

6. *Marshy soils* are formed by the decay of plants, weeds, and other vegetable matter in sluggish water, which, having no current, allows the plants to take root in the bed. When

these plants die, others take their place each year. These successive beds of decayed matter are formed under slight pressure and have innumerable cavities between them, as would a heap of decayed hay, thus forming uncertain foundations for heavy structures. Sometimes these deposits reach such a depth that their bottoms have not been reached. Large areas of marshy lands are formed in this way, by the periodical overflowing of rivers, and the rise and fall of the tides along the coast. The terms *swamp* and *bog* are often used and may be considered here as having the same meaning as marshy soil.

16. During freshets, rivers bring down large quantities of soil held in suspension, which is deposited when the waters subside. This formation is called alluvial, from the Latin word *alluvius*, meaning a washing upon. The term alluvial is often used to designate deposits that are of yearly recurrence, as the Nile and the Mississippi deltas, although the river bottoms of many streams are of this origin. The value of alluvial soil for foundation purposes varies considerably. In many cases, it consists of a clay formation that is hard on top, especially during dry weather, but soft and unreliable underneath. Heavy buildings should not be erected on alluvial ground without a careful investigation of the subsoil by means of borings or trial pits.

Made, or **artificial, ground** may consist of various kinds of materials; such as the refuse of cities, earth and other materials removed from cellars and other excavations, the cinders, ashes, etc. from manufactories and furnaces. It should not be built on, if the structure is of importance, until the nature of its subsoil has been investigated, though for minor edifices a suitable foundation may often be obtained on it.

17. From this description of the soil and materials met with in foundation beds the following deductions may be made:

It is generally safe to build on bed rock any structure that may be required, provided that the foundation beds are kept level.

Gravel, even when mixed with small boulders, can be considered perfectly reliable for any ordinary structure, under usual conditions.

Sand will carry very heavy loads, if it is confined; but great precautions must be taken to properly confine it, and also to keep water from it, especially if running, as the action of water will soon wash it away.

Clay, when compact and dry, will carry large loads, but water should be kept from it, both under and around the structure, the foundations of which might otherwise give way, due to the difficulty of holding back the pasty or semiliquid mass formed.

A thick, hard, or compact stratum, overlying a much softer one, even silt or quicksand, will often carry a considerable load, the hard stratum floating on the soft as a raft floats on the water. It is usually better not to break through this hard stratum, as it serves to spread the base of the building and distribute the pressure over a large area.

The silt, slush, and decayed vegetation contained in the marshy lands, especially in the Southern states, are not fit to build on without piling.

BEARING VALUE OF FOUNDATION SOILS

18. There is some difference of opinion regarding the safe bearing value of foundation soils, due probably to the difficulty of arriving at any experimental results that will have a general application. Conservative engineering practice dictates that the greatest unit pressure on the different foundation soils shall not exceed the values given in Table I.

DEPTH AND AREA OF EXCAVATIONS

19. Cellars for dwelling houses should have a depth of at least 8 feet from the under side of the first floorbeams to the cellar floor, and more depth should be provided where the house is to be heated with a furnace, in order to give sufficient height above the furnace to allow a proper grade to the hot-air pipes. For store, office, and manufacturing buildings, the depth is greater, varying according to the nature of the business carried on, or the requirements of the occupants. In some of the large office buildings in cities, there are three cellars—basement, cellar, and subcellar—and the excavations vary from 25 to 60 feet in depth.

20. That portion of a building from the footing course up to the top of the basement or cellar wall is known as the **substructure,** while that portion of the building above the substructure is known as the **superstructure.**

TABLE I

SAFE BEARING VALUES OF DIFFERENT FOUNDATION SOILS

Material	Tons per Square Foot
Granite formation	30
Limestone, compact beds	25
Sandstone, compact beds	20
Shale formation, or soft, friable rock	8 to 10
Gravel and sand, compact	6 to 10
Gravel, dried and coarse, packed and confined	6
Gravel and sand, mixed with dry clay	4 to 6
Clay, absolutely dry and in thick beds	4
Clay, moderately dry and in thick beds	3
Clay, soft	1 to 1½
Sand, compact, well-cemented, and confined	4
Sand, clean and dry, in natural beds, and confined	2
Earth, solid, dry, and in natural beds	4

21. Care should always be taken, in case there is no cellar under a building, to have the excavation in the trenches go down below the frost line. If the foundations are not started below the frost line, the alternate freezing and thawing of the earth tends to throw the walls out of plumb, and will eventually destroy them, besides racking the superstructure. The depth to which frost will penetrate the earth varies in different parts of the country, but in the Eastern and New England states 4 feet is considered sufficient for ordinary buildings, if the subsoil is satisfactory. Frost will penetrate to a greater depth in hard dense ground than in soft porous earth.

22. In laying foundations below the ground line, it is customary, for the convenience of the mason, to excavate about 6 or 8 inches beyond the line of the proposed wall. This allows the mason, when laying stone or brick, to point the wall on the outside. If concrete is being laid, wooden forms are sometimes used on both sides of the wall, and the 6 or 8 inches between the wall and the earth gives sufficient space for these forms.

23. When making the plans for a building, the character of the ground on which the building is to stand may not be accurately known. Or, while the excavations are being made an underground spring or a bed of quicksand may be encountered, although the soil might have been found solid in several other places tested before the plans were made. Such a condition might necessitate a change in the foundations after the work is begun. It is then very important to revise the drawings, making them conform to the foundations as actually built. At any future time, if it becomes necessary to put up an addition to the building, or to excavate near it, a correct drawing of the foundations will be on hand. Furthermore, the corrected plans will be valuable in calculating the payments to be made to the contractors for additional excavation and foundations.

24. In excavating cellars, it is customary to leave a **runway**; that is, a part of the ground is sloped down from the bank to the cellar bottom, for the more convenient removal of the excavated material. In very deep cellars covering a large area, this runway is usually built of heavy planking supported on wooden beams and posts.

REMOVAL OF MATERIAL

25. Blasting.—In many cases, when rock is encountered, blasting must be resorted to; in cities, this is a separate branch of contracting, and the blasting is usually let as a subcontract.

When a blast is to be made, a hole to receive the powder is first drilled in the rock by hand or power drills; these holes vary in diameter from $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches, and in depth from a few inches to many feet, while the direction varies according to the dip, or slope, of the rock.

The borer, or jumper, used in drilling is a steel-pointed bar. Generally, one man, in a sitting position, directs the drill, turning it after each blow to keep the hole cylindrical, occasionally pouring in water and cleaning out the powdered stone with a scraper. A small rope of straw or hemp is twisted around the drill or jumper at the top of the hole. One or two men strike the jumper with sledge hammers. When a sufficient depth is reached, the hole is dried with a rag on the end of a wire and the explosive is inserted. If the charge is to be ignited with a match, a fuse is placed in the hole, in contact with the explosive, and dry sand, clay, or some similar material is *tamped*, or packed down, around it. When dynamite is used, the end of the fuse in contact with the explosive is provided with a cap, as dynamite can be exploded only by concussion. Frequently, the charge is exploded by electricity, in which case wires must be connected with the explosive before the tamping is done.

In order to confine the pieces of rock, which would otherwise be shot into the air after an explosion, and prevent damage to adjoining property, or possible loss of life, a number of heavy logs, called a **mattress**, are placed over the rock to be blasted. These logs are sometimes bound together by a heavy chain. The weight of the logs keeps the fragments of stone from flying when the charge is exploded.

26. Where extensive blasting operations are going on, rock-boring, or drilling, machines are used, insuring considerable saving in time and labor over the method of hand drilling. In these machines, the drill is repeatedly driven against the rock, either by compressed air or by steam, and made to rotate slightly at each blow. The cost of drilling by the use of rock drills is at least one-third cheaper than by hand power.

27. **Wedging.**—Where rock must be taken out so close to existing walls that injury might result from blasting, the operation of **wedging** is resorted to. This consists of breaking up the rock with wedges. These wedges are made of steel, about 8 inches long, with wire wound about them so as to form a handle. A workman holds the point of the wedge against the rock, and another man strikes repeated blows on the wedge with a sledge hammer until the rock is split or broken.

When the rock breaks easily and is formed in layers with defined seams between them, large quantities may be cheaply removed by this means; but it is a slow and expensive process if the rock is hard and lies in large compact masses.

MEASUREMENT OF EXCAVATION

28. Excavation is usually measured by the cubic yard, or 27 cubic feet, and the price paid varies according to locality, nature of the soil, distance material excavated must be hauled, and disposition to be made of it. Twenty-four cubic feet of sand or 17 cubic feet of earth or clay, when comparatively dry, will weigh a ton. One cubic yard of earth before removal will occupy about 1½ cubic yards when dug, contains 21 struck bushels, and is considered a single cart load.

29. When the ground where a building is to be placed is level or slopes evenly, and when the bottom of the excavation is to be level, it is an easy matter to calculate the number of cubic yards of excavation required. However, if the surface of the ground is very irregular, the amount of excavation is not so easy to ascertain without the use of an

engineer's level. In all cases, it is necessary to decide how the excavation shall be measured before the work is begun. The required measurements can be made on the ground before it is disturbed and again after the cellar has been dug. An easy method of measuring the depth of excavation in a place where the ground level is irregular, is to drive stakes into the ground at intervals before the excavation is started. While the cellar is being dug, these stakes must be left untouched in piers of natural ground until the remainder of the excavation is completed. By measuring the heights of these piers before they are removed, the depth of the excavation can be quite accurately obtained. On the whole, the only very accurate method is to use an engineer's level and survey the ground before excavating is begun.

SHORING, NEEDLING, UNDERPINNING, AND BRACING

SHORING

30. When the foundations of a building, whether new work or an alteration, extend below the foundation walls of adjoining property, *shoring*, *needling*, *underpinning*, and *bracing* must be resorted to, in order to protect the walls of the existing structure.

The contractor is usually held responsible for the successful carrying out of this part of the work, and, consequently, there are in all the large cities firms or individuals that make a specialty of shoring and underpinning. The architect, however, should be familiar with the methods used, and should see that all due precautions for safety are taken and that all the beams, shores, braces, and posts are sufficiently strong to safely carry the loads imposed on them.

31. **Shoring** is a method of temporarily supporting the walls of a building by means of posts or struts set at an angle, to keep the wall from tipping or bulging while the foundations are being carried down, or during the needling and removal of the lower portion of the wall.

The method of shoring the wall for the purposes just mentioned is shown in Fig. 2. Grooves, or sockets, are first cut in the wall, as shown at *a*, *a*, and in these the angle braces, or *shores*, *b*, *b* are inserted. These are also called *spur braces*, and when tightened up by means of screw jacks, instead of the wedges *d*, *d*, they are known as *pumps*. The lower ends of the shoring timbers rest on a timber crib *c*, supported on the ground. Usually two sets of braces are put in, one located near the bottom to support the wall, and the other placed higher up, to keep it from bulging. These two braces, when in place, are often, for further strength, tied together as shown in the illustration by spiking planks to the sides. The crib *c* must be made large enough to distribute the pressure brought on it, over the ground, and the shores should be well wedged with iron or oak wedges, as shown at *d*, *d*. The timbers carrying the ends of the braces should be adjusted to the proper inclination by means of wedges, as shown at *e*, *e*. All piers and chimneys should be separately shored.

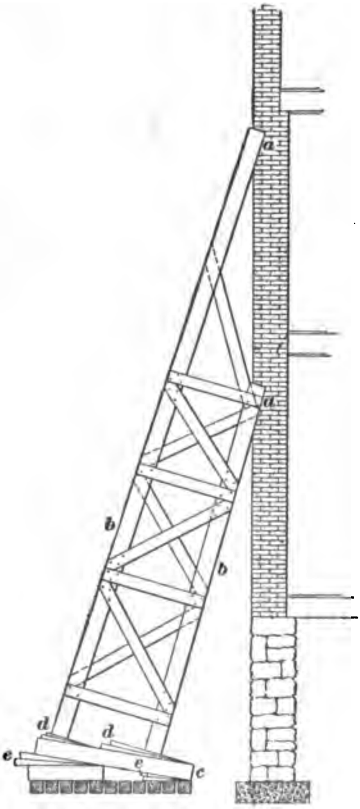


Fig. 2

The foundations should be removed in small portions at a time. When three sets of braces, or shores, are in place, the wall should be underpinned, as hereafter described, after

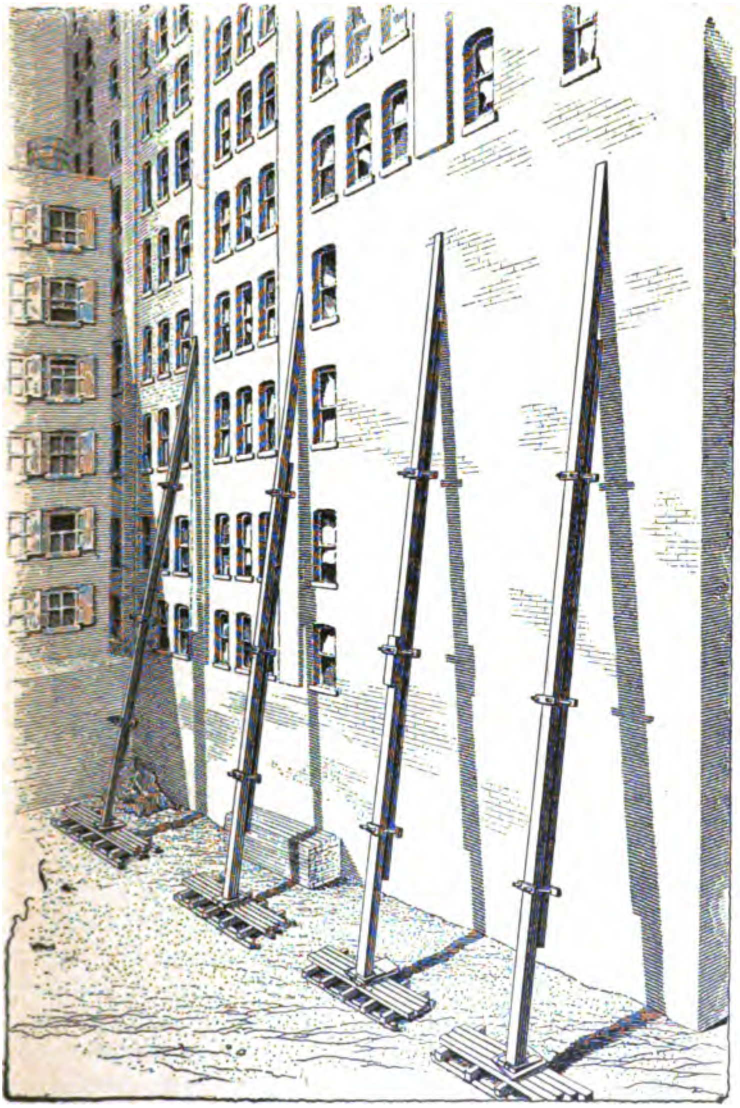


FIG. 8

which the shores over it may be moved along; two sets, however, must always be kept in place.

Fig. 3 shows the method that was used for shoring the walls of the Tribune Building, New York, while the foundations of the adjacent building were being laid. Single shores made of 12″ × 14″ pine, 70 feet long, were used. These shores were each reinforced in the middle by a 10″ × 12″ stick, 45 feet long. This stick was placed on the under side of the shore and held in place by clamps, as shown. The entire upper end of the shore entered the wall and received a bearing through wooden shims. The shores were set in place by screw jacks, giving a thrust of 35 tons on each shore; wedges were then driven under them until the pressure on the jacks was relieved so that they could be removed. The wedges rested on timber cribbings 6 ft. × 12 ft. The slant given to the shores was about 7 to 1.

32. Shoring is often resorted to when it is necessary to hold up the corner of a building, to build a pier, or set a column under it. When a girder is placed under the upper part of a wall, needling is necessary, as being attended with less risk.

NEEDLING

33. When a wall already built is supported on beams or *needles* placed transversely through holes cut in the wall, as shown at *b*, *b*, Fig. 4, and supported at each end by posts, jack-screws, or *pumps*, as shown at *f*, *f*, *f*, it is said to be *needled;* and the operation of preparing it is called **needling.** The illustration shows how a wall is held up by needles in order that a new wall may be built under it, or columns and girders placed to support it.

At *a*, *a* are shown the holes in the wall, cut at intervals to receive the needles *b*, *b*; these needles consist of heavy timbers to carry the upper wall *c*, *c*. Where the needles enter the holes in the wall, small cross-beams *d*, *d* are laid on the upper sides, and wedged in with oak or iron wedges, as shown at *e*, *e*, in order to secure a more even bearing on the wall. At the inner and outer ends of the needles, heavy perpendicular timbers *f*, *f*, *f* are placed to support the needles and carry the weight of the wall. The foot or ground bearing of these timbers is formed by three courses of heavy planking, shown at *g*, *g*, *g*, crossing one another at right angles to spread the weight over a large surface. Wedges *h*, *h*, *h* are driven under the foot of each upright, forcing the ends of the needles upwards until they show a slight downward deflection, or bending, at the center, thus indicating that the weight of the wall is being carried by the needles. As soon as the needles carry the wall, the lower portions may be torn out, and the columns and girders, or other

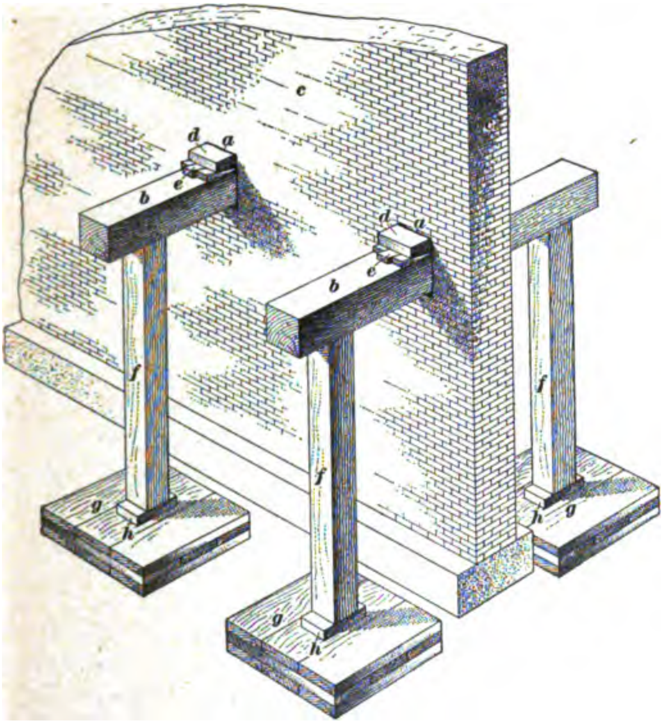


FIG. 4

substructures, are put in place, or the excavation to the lower level begun.

In places where the ground is soft or compressible, sheet-piling is placed around the foot of the uprights, to hold the ground in place.

34. Very frequently, especially for heavy work, when a high wall is to be underpinned, steel beams are used for the needles and jack-screws are placed under the foot of the uprights, or a crib of heavy beams is built up in place of the upright posts.

UNDERPINNING

35. When a new wall is being placed under a wall already built, either to make deeper foundations or on account of the foundations of adjoining structures being built deeper, the operation is called **underpinning.** The old wall is generally supported either by shores or by needles while the new foundation is being constructed. It is often found necessary to tear out the old wall as far up as the needles or shores. The new wall is then built up. In first-class work, the joint between the old and the new masonry is generally made with cut stone, and wedges of stone, slate, or iron. These wedges are driven in between the cut stone of the old and the new work until the weight is taken off the shores or needles. The joint between the two courses of cut stone is then filled with cement mortar and the bracing removed, leaving the wedges permanently in the work. In

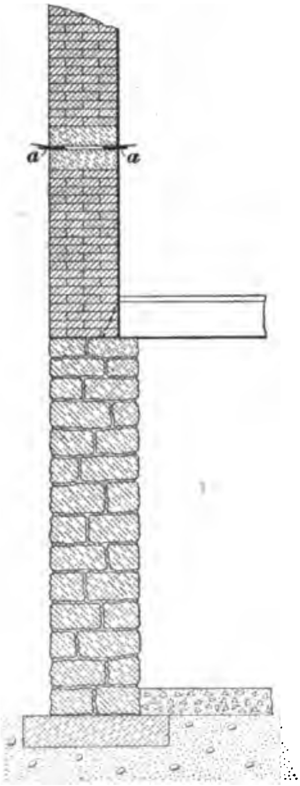


Fig. 5

some work, wooden wedges are used. In very heavy work, iron wedges are usually employed.

36. Fig. 5 shows the method of underpinning a wall. The wedges *a*, *a* are made of slate but are not driven in place. It is important in this kind of work to be careful that the wedges are driven in to the same tightness on both sides; otherwise, there is a tendency for the wall to crack from being supported on only one edge.

37. Underpinning operations should be carefully performed. The underpinning should be done as quickly as possible after the shores or needles are in place, so as not to require their support for a longer time than necessary. However, the needles or shores should not be removed until the cement in the new work has had ample time to set.

BRACING

38. When adjoining buildings have been built originally with party walls, or walls supporting the floorbeams of two buildings, and one of these buildings is to be torn down, the adjacent walls should be guarded against falling by spreading braces or inclined shores. When there are buildings on each side of the lot on which the new building is to be erected, the walls of these structures may be supported by spreading braces.

39. When the distance is not more than 25 feet, the braces may be arranged as shown in Fig. 6. At *a*, *a* are 6″ × 12″ uprights against the walls *d*, *d*, to distribute the bearing of the braces; at *b*, *b* are the spreaders, and at *c*, *c* the angle braces, all of which may be 8″ × 8″ timbers.

When the old buildings are from 40 to 50 feet apart, the spreading braces should be trussed, as shown in Fig. 7. The 6″ × 12″ uprights are shown at *a*, *a* against the walls *e*, *e*; the 10″ × 10″ spreaders at *b*, *b*; the 8″ × 8″ struts and braces at *c*, *c*; and the vertical iron or steel ties at *d*, *d*. It is preferable to use iron or steel rods for these vertical ties, as they can be readily screwed up, and thus overcome any sagging

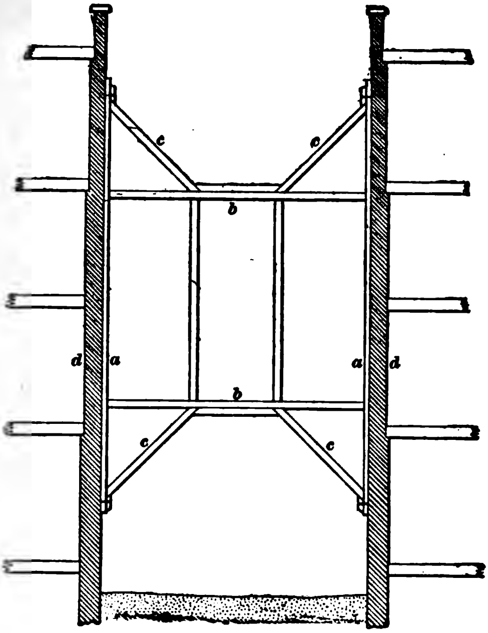


FIG. 6

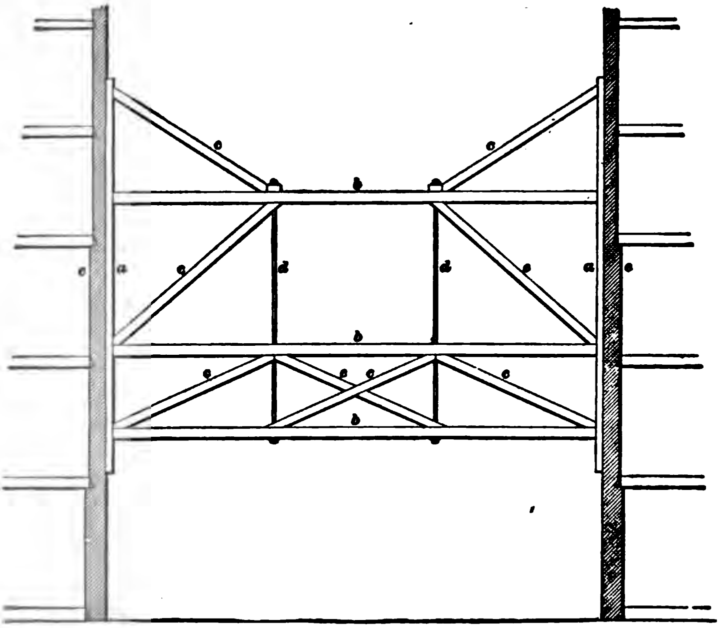


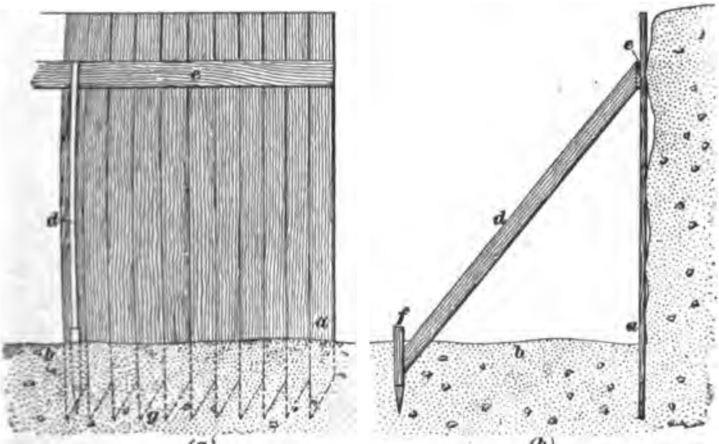
FIG. 7

that may occur in the joints of the truss. One truss should always be placed in the front, another in the rear of the building, and an intermediate one every 25 feet between will generally be found sufficient. Spreading braces are usually built by the carpenter, but it is essential for the architect to know how they should be constructed.

SHEET PILING

40. Wooden Sheet Piling.—Particular care should be taken, especially in cities, to properly protect the adjoining property, sidewalks, etc. from injury by the caving in of the bank during excavation.

To guard against this, the banks or sides of the excavation are sheet piled, as shown in Fig. 8. Sheet piling consists of structural steel, reinforced concrete, or planks pointed at the lower end, placed closely together in line, and driven into the ground against the bank of the excavation so as to form a wall, as shown at (*a*), which is a front elevation of plank sheet piling. At *a* is shown the piling driven into the cellar bottom *b*, against the bank of the excavation. At (*b*) is a section across the piling showing the brace *d* placed against



(*a*) (*b*)

FIG. 8

the batten *e* to retain the piling in place and resist the pressure at the top. The stake shown at *f* is driven in to keep the brace *d* from slipping. These braces are usually spaced about 10 or 12 feet apart, and are necessary when the excavation is a deep one.

The piles are often pointed sidewise as shown at *g*, so that each pile when driven in will tend to press against the one previously put in place.

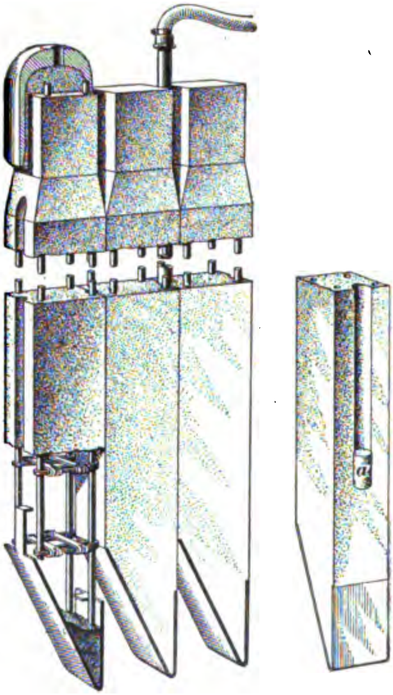


FIG. 9

41. Concrete Sheet Piles.—Fig. 9 shows reinforced-concrete sheet piles. A projection is left near the base of each pile, as at *a*, and a groove runs up both sides of the pile to the top, so that, in driving, the projection on one pile slides in the groove of the one last driven. An iron pipe that fits the grooves of two adjacent piles is connected to a pump. This pipe serves as a guide, and the sand that might jam the grooves is forced out by the water. After the pile is driven, this pipe is withdrawn and a water-tight joint secured by filling the grooves with cement.

BEARING PILES

WOODEN PILES

42. Piles.—A pile may be considered as a column with a base more or less rigid, according to the nature of the soil into which it is driven. If a stick is driven down into damp sand, it will stand upright and support a load, even though it may not have reached a firm bottom, the friction of the sand—or the pressure of its particles against the sides of the stick or pile—holding it in place. Thus, when a pile is driven into the ground, it is held in position by the friction against its sides.

It is usual to excavate to a point below where the heads of the piles are to be cut off, in order that they may be leveled up before the concrete is put in or the foundation begun.

43. Terms Used in Pile Driving.—The technical terms used in pile driving are descriptive of the form or position of the piles, or the manner of their driving.

A **close pile** is one set close to another when the pile already driven shows signs of weakness.

A **false pile, or follower,** is an additional length added to a pile for deeper driving. Fig. 10 shows the manner of connecting the first pile driven and the follower; *a* is the first pile, *b* is the follower, and *c* is a dowel to preserve the alinement of the two piles. At *d*, *d* are shown wrought-iron straps, made usually of 2″ × ½″ × 20″ iron, to bind the two piles together.

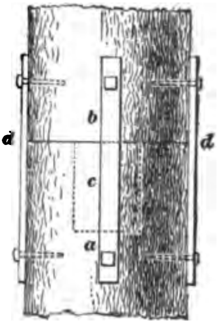


FIG. 10

A **wale** is a horizontal string piece to bind the piles together.

Pile hoops are bands placed around the tops to prevent splitting.

44. The common timber pile is the one that particularly interests the architect. Except for large work, it is seldom that he uses the concrete or any other pile. He should, however, have a general knowledge of the various styles in use.

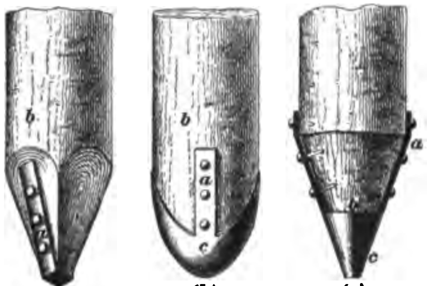
45. Piles are generally round, and from 9 to 18 inches in diameter at the head. They should be straight and free from bark and projecting limbs; but where piles are exposed to the rise and fall of tides, it is considered best to drive them with the bark on, since they are then not so easily affected by the action of sea-water, and are not likely to be attacked by the *Teredo navalis* and other boring sea worms.

Oak, spruce, hard pine, cypress, and elm are the principal woods used for piling. Oak has the advantage of being hard and tough, and stands hammering well, but cannot be obtained in as large, straight, or long pieces as spruce, hard pine, or cypress. The long-leaf pine is hard and tough and can readily be obtained in good-sized logs of lengths up to 90 or 100 feet, and from 12 to 18 inches diameter at the butt, and from 5 to 12 inches thick at the lower end.

46. Piles are usually driven with their small ends down. The butt end is cut off square, to receive the hammer squarely. The small end is usually pointed to an angle of about 30° and is often shod with iron. If the pile is to be used in very soft soil, it is often better to leave the small end blunt, because, when the pile has but little lateral support, any small obstruction is liable to deflect the pointed end, while a blunt pile will drive such small obstacles before it.

47. The large end of the pile should be cut, or chamfered, for a few inches from the end, so that a wrought-iron ring, 1 inch in thickness and 3 inches wide, will fit over the end of the pile tightly when struck one or two light taps with a hammer or ram. Sometimes a ring from 1 to $1\frac{1}{2}$ inches less in diameter than the pile is simply placed on the top of the pile, and driven into it with light blows. This, however, is not so desirable as the former method, as the ring is liable to split long pieces from the sides of the piles, and not usually being put on until the pile is more or less battered on the end, is likely to be carelessly placed, and not concentric with the head of the pile. The rings are used in pile driving in order to lessen the tendency of the pile to split or broom. **Brooming** is a term applied to the splintering of the fibers on the end of the piles, due to repeated blows of the ram.

48. **Shoeing Piles.**—When piles are driven through soft material to rock or hard gravel, the force of the blows of the hammer has a tendency to split the piles, after rock or hard gravel has been reached, thus greatly impairing their bearing capacity; to prevent this, piles are often protected at the end with wrought- or cast-iron shoes. Fig. 11 illustrates three methods of shoeing the ends of piles. At (*a*) is shown a $2'' \times \frac{1}{2}''$ wrought-iron strap *a* bolted through the pile *b*, forming a shoe, which is the same on both sides of the pile. At (*b*) is shown a cast-iron conical shoe fitted over the end of the pile *b*; the head of the shoe *c* protects the end of the pile, and the straps *a*, one on each side, hold the shoe in place. One of the best forms of cast-iron shoes is shown at (*c*). In this case, the pile has a blunt end from 4 to 6 inches in diameter shown at *b*. The shoe has a solid conical point *c*, the top of its base being about the same diameter as the end of the pile; the straps then extend up on the sides of the pile, and are bolted or spiked to it, as shown. The straps and bolts hold the shoe in place while it is pushed through the soil. A shoe of this kind will, to a great extent, prevent the end of the pile from brooming.



(*a*) (*b*) (*c*)

FIG. 11

49. **Protection of Piles.**—When timber foundations have to be constructed, and the piles are exposed to sea-water,

they are liable to be attacked by various wood-boring worms that will penetrate the piles and destroy ordinary timber in from 3 to 5 years. The bark is therefore often left on, for they do not often bore through the bark of piles, which seems to kill them before they can penetrate it.

To prevent the attack of these destroyers, the piles are often treated with creosote, or the heavy oil of tar. The sap and moisture are exhausted from the wood by creating a partial vacuum in an air-tight vessel or tank, in which the piles have been placed, and then forcing the creosote into the pores of the timber under a heavy pressure. By this means, the depredations of the *Teredo navalis*, or sea worms, are almost completely checked. Wooden piles are frequently charred slightly on the outside, to allow the creosote to penetrate more readily. The charred wood also prevents the sea worms from eating through, by reason of the fact that it affords the pest no nourishment.

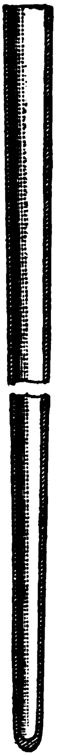


FIG. 12

METAL PILES

50. **A cast-iron pile** is shown in Fig. 12. This type of pile, owing to its original cost and the difficulty experienced in driving it, is not extensively used.

SCREW PILES

51. **A screw pile** is shown in Fig. 13. Screw piles are forced into the ground by means of a cast-iron screw on their lower end. This screw is usually about 4 feet in diameter, and has a pitch of about 7 inches. The shaft may be of wood, steel, or cast iron. However, it is usually made of hollow metal and provided with teeth *a* on its lower edge to assist in cutting. Screw piles are driven by a capstan and levers fixed at the top. As the pile

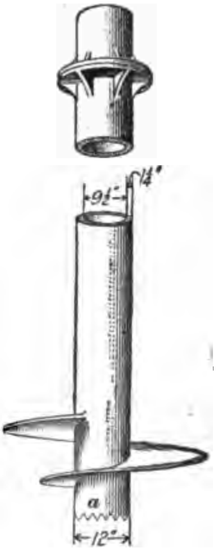


FIG. 13

descends, lengths of pipe are added. Such piles may be used in most soils, as they will sink through sand or gravel and even small boulders. Hollow cast-iron piles, when used as screw piles, are frequently filled with concrete after they are in place, to strengthen them and increase their bearing surface. A screw pile can be sunk near a building where the shock from a pile driver on an ordinary pile would be dangerous.

PNEUMATIC PILES

52. Pneumatic piles are cylinders, or caissons, of steel or cast iron that are sunk by excavating from the inside. The pressure of air maintained within them prevents an influx of water. When the piles have been sunk to the proper depth and the interior excavated, they are filled with concrete.

DISK PILES

53. A **disk pile**, Fig. 14, usually has a cast-iron disk *a* on a steel shaft *b*. It is sunk by washing away the earth beneath it with a stream of water.

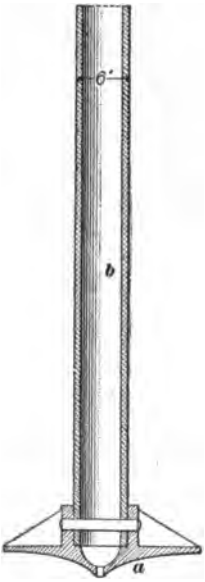


FIG. 14

SAND PILES

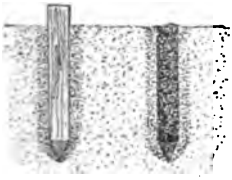


FIG. 15

54. A **sand pile**, Fig. 15, is made as follows: An ordinary pile is driven into the ground 5 or 6 feet and then withdrawn. This operation leaves a hole with the soil packed tightly around it. The hole is then filled with sand. The sand is put in, a few inches at a time, and tamped; then more sand is added, being tamped every few inches, and so on, until the hole is filled. This method of piling is very successful in soft clay. The holes may be made with an auger instead of a wooden pile, although a wooden pile is preferable, as it compresses the soil at the sides. The bearing power of a sand pile depends as much on the friction against the sides, due to the arching of the grains against one another, as on the direct load carried to the bottom of the hole.

CONCRETE PILES

55. The usual form of concrete pile is shown in Fig. 16. The pile has an iron shoe *a* as shown, and is reinforced by four steel rods. These rods are laced together by wire at regular intervals. A cap of steel, which is put on the pile while driving, is shown at *b*. The cap is filled with sand, as shown at *c*, and this sand acts as a cushion to distribute the force of the blow evenly over the top of the pile. The sand is kept in the cap by clay, as shown at *f*, which is in turn held in by hemp packing shown at *g*. Concrete piles should be made at least 30 days before being used. They are more durable and stronger than wooden piles but also are more expensive.

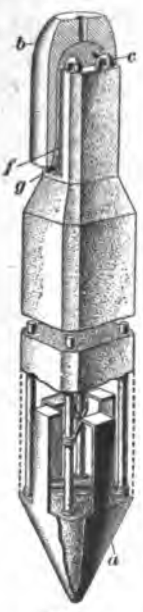


FIG. 16

DRIVING PILES

56. Piles are usually sunk by a machine called a **pile driver**, which consists of a frame made of two vertical guides, usually of wood, between which slides a weight. The pile driver is placed over the pile to be sunk and the weight is hoisted to the top of the guides by a rope that passes over a pulley on the top of the frame and then down, generally to an engine drum. After the weight is hoisted to the top of the frame, it is released and falls on the head of the pile. This operation is repeated until the pile does not sink more than from ¼ to 1 inch under one blow of the weight or *hammer*, as it is often called. This hammer generally weighs about 1,500 pounds and falls about 20 feet on the head of the pile below.

When the weight of the hammer and the height from which it falls are known, the distance a pile sinks at the last blow determines approximately the load it will carry.

CALCULATIONS FOR PILES

57. The efficient bearing capacity of piles in different soils is very indefinite. A pile may go down through a stiff clay or gravel for some distance, sinking very little at each blow of the hammer, and may then penetrate a soft stratum, so that the pile will sometimes sink nearly as much at the last blow as at the first. In this case, the friction on the sides of the pile keeps it in place. But this friction is so great that even in marshy ground the ultimate bearing capacity of a pile 30 feet long is given as from 13,000 to 20,000 pounds, or from 6½ to 10 tons. In alluvial soil, or moderately soft clay, the bearing capacity is from 20,000 to 40,000 pounds, or 10 to 20 tons; and in stiff clay, or compact sand, from 40,000 to 100,000 pounds, or 20 to 50 tons.

58. Having the weight of the hammer, the height it falls, and the penetration of the pile at the last blow of the hammer, the following rule may be used for determining the ultimate load a pile will carry:

Rule.—*Multiply the weight of the ram, in pounds, by the height it falls, in inches, and divide the product by 1 plus the set or penetration, in inches, at the last blow of the hammer.*

Expressed as a formula:

$$P = \frac{Wh}{(a+1)}$$

in which h = fall, in inches;
W = weight of hammer, in pounds;
a = penetration at last blow, in inches;
P = ultimate load, in pounds.

In pilework, it is customary to allow only one-sixth of the total or ultimate load for the safe load a pile should carry. Calling the safe load, in pounds, p,

$$p = \frac{P}{6} = \frac{Wh}{6(a+1)}$$

Example.—The weight of a pile-driver hammer is 1,500 pounds; height of fall, 15 feet, or 180 inches; penetration of pile at last blow, 2 inches. What is the safe bearing capacity of the pile?

Solution.—

$$p = \frac{180 \times 1{,}500}{6 \times (2+1)} = 15{,}000 \text{ lb., or } 7.5 \text{ T.}$$

the safe load the pile will carry. Ans.

59. In all calculations of the bearing power of piles, a large safety factor is necessary, owing to the many uncertainties connected with the subject. The New York building laws require that a pile shall not be less than 5 inches in diameter at the smallest end, and that when walls, piers, or posts rest on them, they shall be spaced not more than 30 inches on centers, and shall not carry more than 20 tons to each pile.

FOOTINGS AND FOUNDATIONS

FOOTINGS

DESIGN AND CONSTRUCTION

PURPOSE OF FOOTINGS

1. If a man stands on soft mud, marshy ground, or quicksand, he sinks to a greater or less depth, proportional to his weight. If, however, he stands on a plank or wooden platform, or on a post or posts driven through the mud or marsh to firmer ground, his weight is distributed over a larger area in the first case and carried down to a better foundation in the second.

It is similar with the footings of buildings. By spreading the load, or weight of the structure, over a larger area or bearing surface, the weight of the building is more evenly distributed, and the likelihood of a settlement, due to compression of the ground, is much diminished. For this reason, the higher and heavier the building is to be, the wider and deeper the supports or footings for the foundation must be; and if extremely soft or yielding ground is encountered, piling should be resorted to in order to carry the weight of the building to a more solid base.

2. Footings may be of iron, timber, large flat building stones, laid directly on the ground or on a bed of concrete, or they may be of concrete alone or with reinforcement, or

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concrete and stepped-up brickwork. Where piling is used, heavy capping timbers are often placed on the heads of the piles, with either stone or concrete footings resting on them; or large footing stones may be laid directly on the piles.

TIMBER FOOTINGS

3. Timber is often used for footing courses where a large bearing surface is necessary, and can be obtained, provided always that the timber can be kept from rotting. In some cases, the timber is charred on the outside; and in other cases, it is coated with asphalt. If the ground is continually wet, there is little to fear, as timber will not decay when kept constantly saturated with water; but when alternately wet and dry, unprepared timber cannot be depended on.

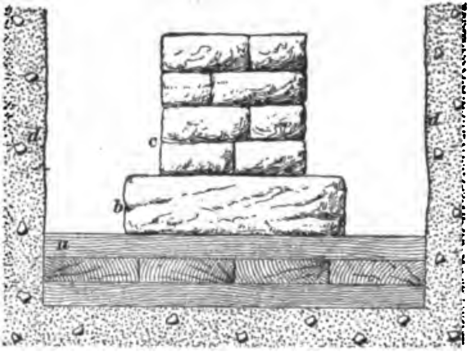


FIG. 1

The best method of placing planks under walls for footings is to use 3″ × 12″ plank cut in short lengths and laid crosswise in the trench. A layer of plank of the same size is then laid lengthwise, followed by a third layer again placed transversely. In Fig. 1, *b* is the stone footing resting on the footing planks *a*, and carrying the stone foundation wall *c* between the sides *d*, *d* of the trench.

CONCRETE AND STONE FOOTINGS

4. Fig. 2 shows a 20-inch brick wall *b*, on a concrete footing *a*, 20 inches thick and 36 inches wide. Figs. 3 and 4 show the concrete base *a*, and stepped-up brick footing courses *b*. In Fig. 3, each step of brickwork is set back 2 inches for each course; while in Fig. 4, each step is set back 4 inches for each two courses. At *c* is shown a 20-inch brick foundation wall resting on the stepped-up brick footing.

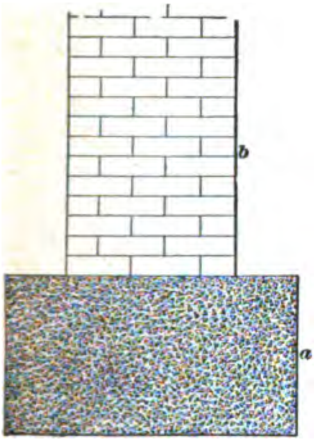


FIG. 2

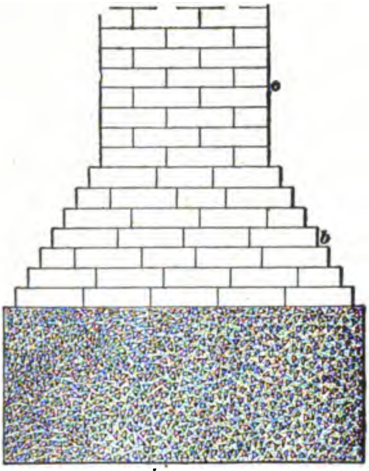


FIG. 3

Fig. 5 illustrates a stone footing *a*, *a* composed of three courses of flat stone, each course being 8 inches thick. The top course has a projection of 6 inches on each side of the 20-inch brick foundation wall *b*, and the middle and bottom

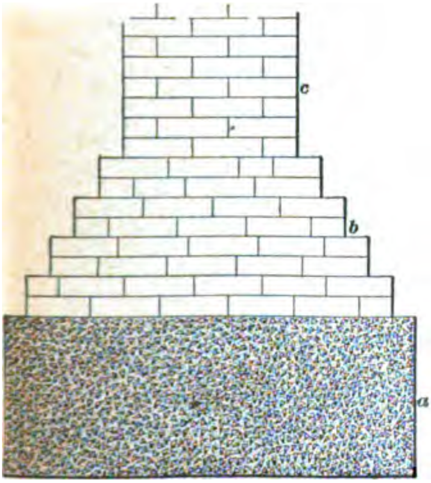


FIG. 4

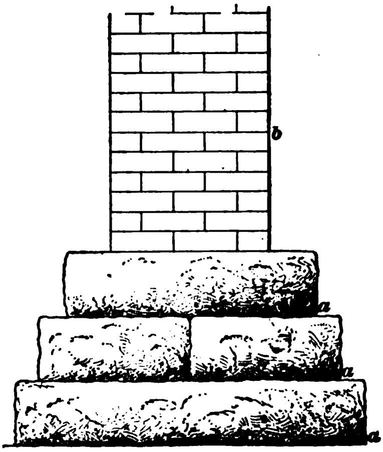


FIG. 5

courses each project 3 inches, making the width of the bottom stone 3 feet 8 inches.

Fig. 6 shows a stepped-stone footing *a*, *a* in section, similar to that shown in Fig. 5, but supporting a 24-inch stone foundation wall *b*. Each base course advances 3 inches beyond the one above.

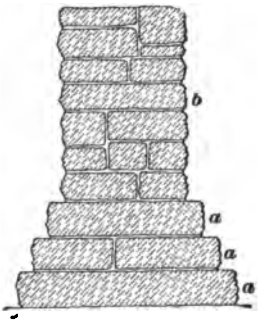


FIG. 6

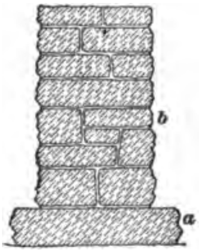


FIG. 7

Fig. 7 shows a footing consisting of a single course of stone *a*, 8 inches thick and 28 inches wide, carrying the stone wall *b*, 20 inches thick.

5. As a rule, concrete, when of sufficient depth and width, and when properly made and laid, makes the best footing course. Concrete for footings should be made of one part good cement, three parts clean, sharp sand, and six parts sharp, broken stone. In very important work, such as bridge piers, and the footings of very tall buildings, chimneys, etc., a proportion of one of cement, two of sand, and four of broken stone is generally used. The New York building laws call for one of cement, three of sand, and five of broken stone.

None of the stone used in making concrete should be larger than will go through a 2-inch ring. In localities where stone cannot readily be obtained, broken brick or terra cotta may be used in the same proportion as stone, care being taken to use good hard-burned material.

Well-broken foundry slag and scoriæ, steam-boiler ashes from anthracite coal, and clean-washed gravel, mixed in the proportions given, make good concrete, though gravel, being rounded and smooth, does not adhere to the mortar so well as does broken stone, slag, brick, or scoriæ.

No concrete should be made unless it is to be used at once, because the cement, forming its most essential part, sets or hardens quickly, and if it sets before being put in place, it is valueless.

6. As soon as the concrete is thoroughly mixed, it should be conveyed to the footing trenches and put down in layers of from 6 to 8 inches thick. As each layer is put down, the concrete should be well rammed with a wooden rammer, until the water *flushes*, or shows on top of each layer. This method causes the layers to unite, and make one solid homogeneous mass, and is preferable to throwing the concrete from a platform into the trenches, as by the latter method the concrete does not become consolidated.

Should one layer have become partly set before another layer is put down, the concrete should be swept clean, scratched with a rake, and well moistened with water before the next layer is put in place.

Sometimes, it becomes necessary to lay concrete in running water, and unless some means is devised to protect it during the laying, the water will wash the cement away from the concrete and weaken it. This is prevented by making large bags of oiled cotton, filling them with concrete, and then lowering the bags of concrete into the excavation; the concrete will then set before the water can wash out the cement.

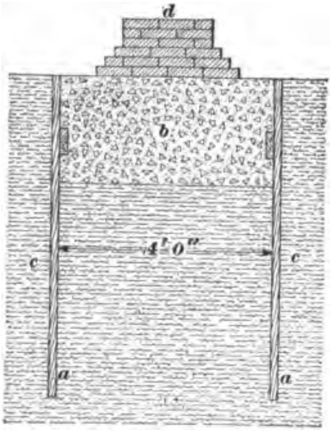


FIG. 8

7. Quicksand, when confined, can be safely built on. Fig. 8 shows a method of confining quicksand by sheet piling, and placing concrete between the piling. The sheet piling shown at *a*, *a* is placed, in this case, 4 feet apart; the concrete shown at *b* is 2 feet thick and extends the full width of the piling; the quicksand, through which the sheet piling is driven, is shown at *c*, and the 20-inch brick foundation wall, at *d*.

8. Fig. 9 gives an example of a footing composed partly of timber. This was placed near the water-line of a marsh in New York state, to carry a factory building 50 ft. × 80 ft. and 40 feet high. The soil was a stiff black muck, and at a depth of about 5 feet, water-soaked sand was found. After the trenches were dug, a bedding of concrete *a* 12 inches thick was laid. On top of this, 2-inch spruce planks *b* were placed crosswise, followed by 8″ × 8″ timber *c*, laid parallel with the trenches and filled in between with concrete. On this were laid the base stones *d*, and on top of these was built a 20-inch foundation wall *e*. The trenches on each side of the wall were filled in with sand, rammed down, as shown at *f*.

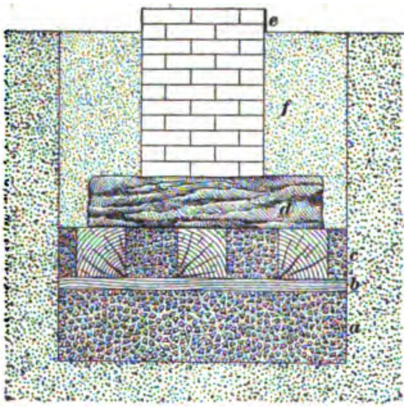


Fig. 9

This factory has an engine, shafting, boiler, and machinery, and employs over one hundred operatives, yet no settlement has occurred, though it has been built a number of years.

9. Stone-footing courses should be laid with large flat stones not less than 8 inches thick. If more than one course is laid, the joints should never come over each other, as that would defeat the object of bonding, which is to firmly tie together the parts of the wall.

All stone footings should lie on their natural, or quarry, beds, and all the joints and spaces between the stone must be well filled with mortar, because the mortar acts as a bedding between the stones, and unless this were interposed, the uneven pressure of one stone on another might cause a fracture of one and produce settlement.

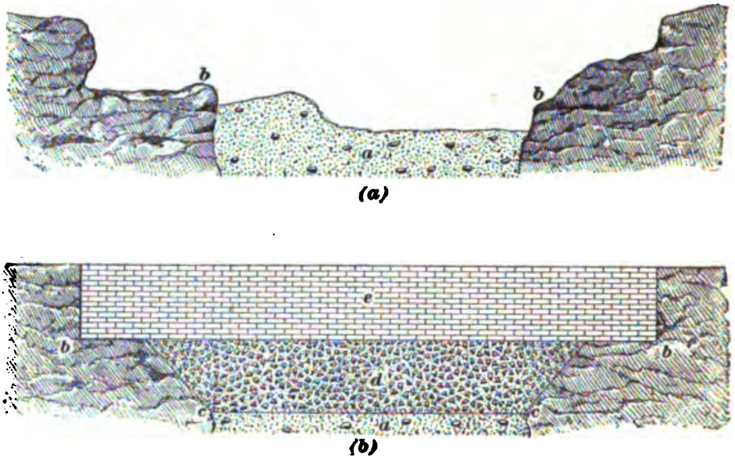
10. All footing courses, as indeed all mason work below ground level, should be laid in cement mortar, although in dry, well-drained soil, lime-and-cement mortar may be used. The usual proportion of cement and sand for cement mortar is one part of cement and three parts of sand. The proportions of cement-and-lime mortar are one of cement, one of lime, and four of sand. The proportions just stated are from the building laws of New York, and have been found suitable for general mason work.

11. Stepped-up brick footings having concrete and stone bases, as shown in Figs. 3 and 4, are often used. The pyramidal form of stepped-up brickwork carries the load of the superstructure more evenly to the footings and reduces the risk of settlement or fracture. This form of footing is used very extensively for piers supporting iron columns. Nothing but good, hard, well-burned brick should be used; and they should be laid in cement mortar, and should break joints—that is, no two joints should come over each other.

FOOTINGS ON ROCK AND GRAVEL

12. In placing foundation footings on rock, it is sometimes found that some portions of the footings will rest on the rock, and others, owing to the diversified character of the surface, will rest on clay, sand, or gravel. The settlement of the foundation walls—and as a necessary consequence, that of the whole building—will then be uneven, as the walls resting on the rock will not settle, while those resting on the sand, gravel, or clay will, by compressing the material on which they are carried.

13. Fig. 10 shows the method employed to obtain equal settlement. At (*a*) is shown the rock and gravel before leveling or excavating; *a* indicating the clay or sand and *b*, the rock. It is customary to remove the rock to a certain level, as shown in (*b*). The softer soil *a* is then removed and leveled off, as at *c c*, and a bed of concrete about 3 feet thick, as shown at *d* is then put down, the concrete being brought to the level of the rock, and on this the brick or stone foundation wall *e* is built.



(a)

(b)

Fig. 10

14. It is not considered necessary, on solid rock, to have the footing bed cut level over its entire surface, nor even cut into a series of horizontal surfaces resembling steps, as is frequently done in softer soils, which method costs a great deal of time and money; but it is necessary that the surface of the rock shall be so roughened that the possibility of the footing slipping on its foundation will be prevented. After this is done, concrete may be put in to bring the foundation to its proper level. When the structure is three or four stories in height, stone or brick may be used in place of concrete, but a concrete base is usually considered preferable.

FOOTING ON SLOPING GROUND

15. Footing courses built on slopes—especially of clay—are always likely to slide. This may be avoided by cutting horizontal steps in the slope as shown in Fig. 11, where the slope *e f* is stepped off, as shown at *a a*, in order that the footings *b b* may have a horizontal bearing. These footings may be of either stone or concrete, but when the former material is used, great care must be exercised to secure a perfect bond at the stepping places, and the foundations should be laid in as long sections as possible.

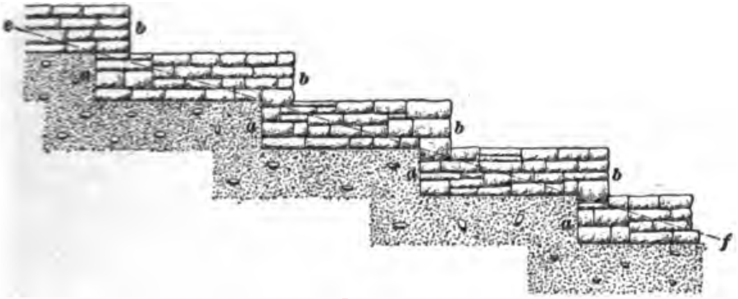


FIG. 11

SPREAD FOOTINGS

16. It is often found that compressible soils, even alluvium and soft clay, will bear from 1 to 2 tons per square foot with but little settlement, and under a steady load, this settlement is in most cases uniform. It very often is cheaper, therefore, to spread the foundation over a large area than it is to drive piles.

In Chicago, for example, the subsoil extending from 5 to 8 feet below the street grade is of blue clay. This clay bed, when below the level of ground or drainage water, becomes quicksand or blue mud, and has a bearing capacity of only a little over 1 ton per square foot, so the heavy weights of the high buildings are carried on spread foundations. This plan is usually adopted in the Chicago soil, because the quicksand or muck substratum is of great depth, and piles driven through the stiff upper stratum sink 2 or 3 feet at every blow of the hammer, and are held solidly only at the top and the bottom.

REINFORCED-CONCRETE FOOTINGS

17. Spread footings may be built either of concrete with steel tension rods or netting, or with a base of I beams or steel rails, bedded in concrete, or of timber and masonry as previously described.

Concrete footings can be made much shallower and cheaper by using some form of tension bars or netting on the under side than by making them of concrete alone. This method, besides saving excavation and concrete, will also gain space in the basement of a building, which is of great importance in the modern office structure.

18. A concrete base under a column has a tendency to break, as shown in Fig. 12. The fibers of the material at *a* are in tension and the fibers at *b* are in compression. Concrete 1 month old, made of good Portland cement, has a compressive strength of about 2,000 pounds per square inch, while it has a tensile strength of only about 200 pounds per square inch. Therefore, in a spread foundation the danger is from the concrete rupturing at *a* rather than crushing at *b*, as can be seen from the figure. To remedy this defect, steel is embedded in those portions of the footing that have to resist tension. Thus, the concrete cannot fail in those places unless the steel also gives way. The tensile strength of steel is about 65,000 pounds per square inch, and, consequently, a small percentage of steel will be sufficient to hold concrete together.

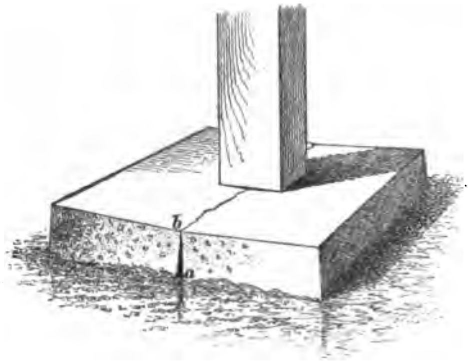


FIG. 12

19. Footings Reinforced With Steel Bars.—There are various ways to reinforce concrete with steel. Probably the method most frequently used is to embed ordinary round steel rods in the concrete. In the last few years, however, many patent bars, with corrugated or twisted surfaces, have been put on the market. The makers of these bars claim that there is a tendency for the smooth bars to slip through the concrete, and that twisted or corrugated bars increase the grip of the concrete on the steel. Fig. 13 illustrates three makes of these bars: (*a*) represents a bar used in the Ransome system of reinforced concrete; (*b*) is a bar patented by the Expanded Metal Company; and (*c*) is a Thacher bar.

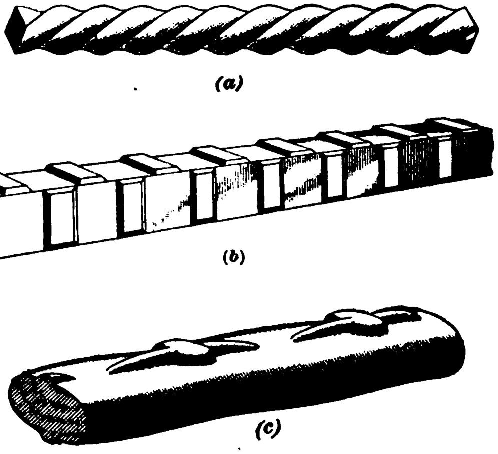

(*a*)
(*b*)
(*c*)

FIG. 13

20. Whether it is better to use a few patented bars for a certain piece of work or a greater number of ordinary round bars is simply a question of expense. The patented bars cost more but are more efficient and the question of using them will depend entirely on the extra cost. The increase in cost over the ordinary round bars is due to the fact that the former are patented and more labor is required in their manufacture.

21. Footings Reinforced With Expanded Metal. Another kind of reinforcement that is sometimes used for foundation work is **expanded metal**. This is made from sheet steel. Slits are cut in the steel by a special machine and the sheet is then stretched out, or expanded. Fig. 14 shows a sheet of metal in which the slots have been cut and which has been partly expanded.

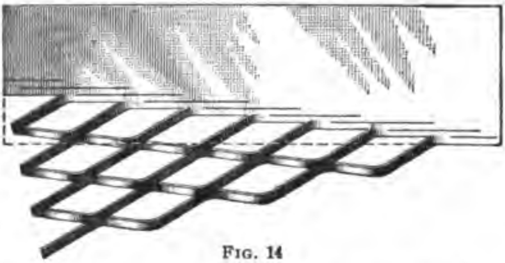


FIG. 14

22. Fig. 15 shows a section of a concrete footing reinforced with steel rods of the Ransome design. The rods are laid in rows at right angles to each other, as shown at *a* and *b*. In building these footings, a layer of concrete from 3 to 6 inches thick should first be laid and the first tier of longitudinal bars placed and tamped. Another layer of concrete 4 inches in thickness is spread and the transverse bars are then laid; in this manner, as many

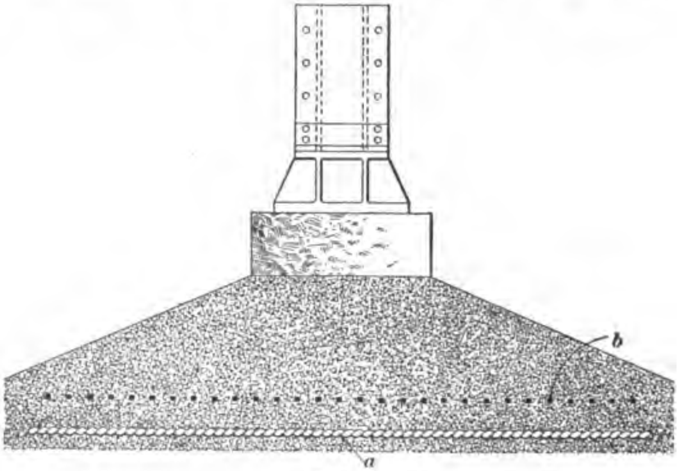


FIG. 15

courses of concrete and steel as are necessary may be laid and tamped.

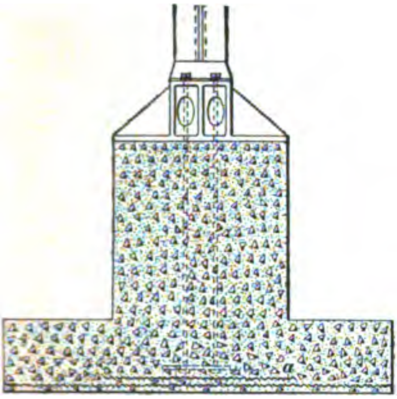
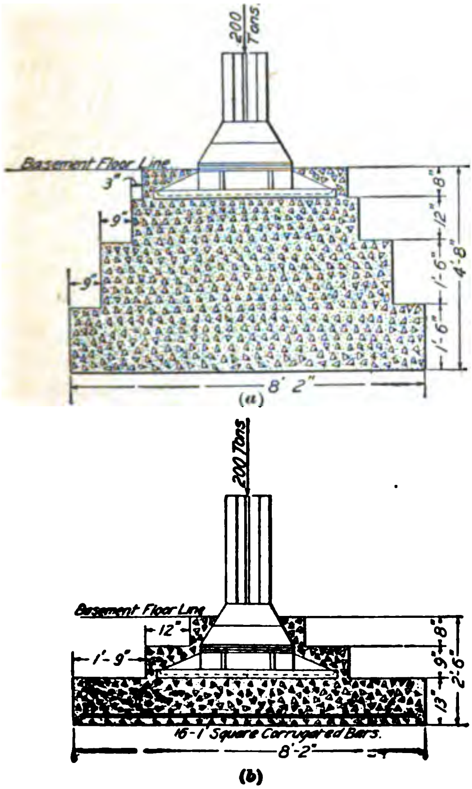


Fig. 16

23. Fig. 16 illustrates a spread foundation reinforced with expanded metal, which is laid in the same manner as the bars in Fig. 15. The strain on the footing is greater in the center than toward the edges; therefore, an extra piece of expanded metal shown at *a* in the illustration is placed in the middle of the footing to help support this strain.



(*a*)

(*b*)

Fig. 17

24. Fig. 17 illustrates the saving of material and labor over plain footings, in building footings of concrete, by using steel reinforcement. At (*a*) is shown a footing without steel reinforcement, while at (*b*) is shown a footing designed for the same strength but reinforced with rods manufactured by the Expanded Metal Company. The cost of the footing shown in (*a*) is as follows:

Excavation, 11.53 cubic yards at 75 cents .	$ 8.65
Concrete, 202.3 cubic feet at 26 cents . .	52.60
Total cost of solid-concrete footing . .	$61.25

The cost of the footing shown in (*b*) is as follows:

Excavation, 6.18 cubic yards, at 75 cents . .	$ 4.64
Concrete, 86 cubic feet, at 26 cents	22.36
Extra length of column, 53 pounds, at 3.5 cents	1.86
Corrugated bars, 720 pounds, at 3 cents . .	21.60
Total cost of reinforced-concrete footing	$50.46

Both of the footings shown in Fig. 17 have been proportioned to sustain a column load of 200 tons.

25. Footings Reinforced With I Beams.—When buildings are constructed on solid ground, it is claimed that steel or iron footings are cheaper than masonry. Owing, however, to the danger of rusting in steel, it was considered doubtful some years ago if steel footings could be made as durable as those composed of masonry. Today, however, architects and engineers have much more confidence in the ability of concrete to preserve steel from rusting. Many reinforced-concrete structures—as water mains and building foundations—have been buried in the earth for some years and upon being taken up it is found that the steel is in almost perfect preservation. It is claimed that the concrete in contact with the steel prevents it from rusting by its chemical action, even when the latter is moist. In ordinary reinforced-concrete work no particular precaution is taken, but in footings reinforced with I beams more care is usually employed in placing the steel, to be sure to be on the safe side.

In preparing the footings for laying steel beams, the bottom of the pier must first be located, and the ground carefully leveled. When the ground is of soft material and the sides of the excavation are in danger of falling in, heavy planks or timbers should be set up and fastened together at the corners, to hold the concrete in place and prevent its spreading before it is thoroughly set. Portland-cement concrete, made of one part cement, two parts sand, and four parts broken stone, should then be laid in layers of from 6 to 12 inches, according to the weight on the footings. If this concrete bed is 12 inches thick, it should be made in two layers. On the concrete, the iron or steel beams should be bedded in mortar made of one part Portland cement and two parts sand, so as to make them level and in line with one another.

All iron or steel beams should be thoroughly cleaned with wire brushes, and, when absolutely dry, painted with metallic paint, or heated and coated with two applications of hot asphalt. The beams should be very carefully examined before covering them with the concrete, and if any of the paint or asphalt has been scraped off, the coating should be renewed. Every possible means should be used to keep the beams from rusting, for when unprotected they rust very quickly.

26. The I beams may be variously spaced from 10 to 20 inches between centers, according to the weight of the beams, thickness of concrete, and weight of superstructure, and should be held in place, relative to one another, by means of separators and tie-rods. They should not be spaced so far apart as to crush through the concrete, and a space of at least 2 inches should be left between the edges of the flanges, so that the concrete filling may be placed between the beams. This concrete filling should be made in the same proportion as the concrete bedding, but the stone used for the aggregate must not be larger than will go through a 1½-inch ring, and the concrete should be well rammed so that no voids will be left. It should also be carried not less than 3 inches beyond the sides and ends, and kept in place by planking or timbers.

27. If there is more than one tier, or layer, of beams, the top of each layer is sometimes leveled, after the concrete has been rammed in place, with cement mortar, made of one part Portland cement and two parts sand, laid about ½ inch thick over the top of the highest beam, and on this the next layer of beams should be laid.

Some suggest that two thicknesses of tarred felt be laid in hot asphalt on top of the concrete before the beams are laid, and on this 1½ inches of 1-to-2 cement mortar, on which the beams should be placed. The same authorities also recommend that the whole exterior of the footing be covered with two coats of hot asphalt put on over the cement.

The iron base plate or stone footing should be bedded in about ¾ inch of cement mortar. After this is set, the whole of the beam footing—top, sides, and ends—should be covered with at least 3 inches of Portland-cement mortar made in the proportion of 1 to 2.

28. An example of the use of I beams is shown in Fig. 18. The 10-inch I beams *b* run transversely under the walls and are supported by the layer of concrete *a*, 12 inches thick. At *c* is shown the concrete on top of the I beams; at *d*, the stone-footing courses of the foundation; and at *e*, the foundation wall. When spread foundations are built under isolated piers, especially when they support iron columns, a somewhat different form of construction is usually adopted.

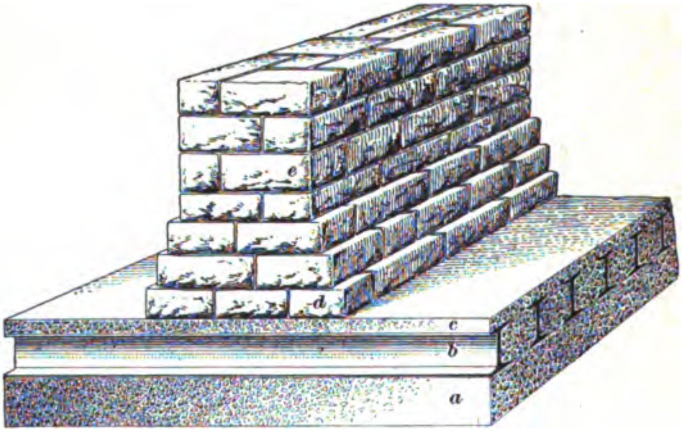


FIG. 18

29. Fig. 19 shows the arrangement of I beams under a pier. At *a* and *b* in the plan (*a*) are shown the I beams, and at *c c*, the foundation. The upper tier of beams *b* is laid transversely on the lower tier *a*, and the stone footings *c c* carry the 3-inch iron plate *d* under the column.

At (*b*) is shown a section taken on line *l m* on the plan (*a*), where the concrete base, on which the lower tier of I beams rests, is shown at *e*, the lower tier of 10-inch I beams at *a*, and the concrete around the upper tier of beams at *f*; *b* is the upper tier of 10-inch I beams shown in section, and *c c*, the stone-footing courses under the iron plate *d*.

At (*c*) is shown a view of the pier taken on line *n o*, on the plan (*a*), which represents the lower tier of I beams in section and the upper tier in elevation.

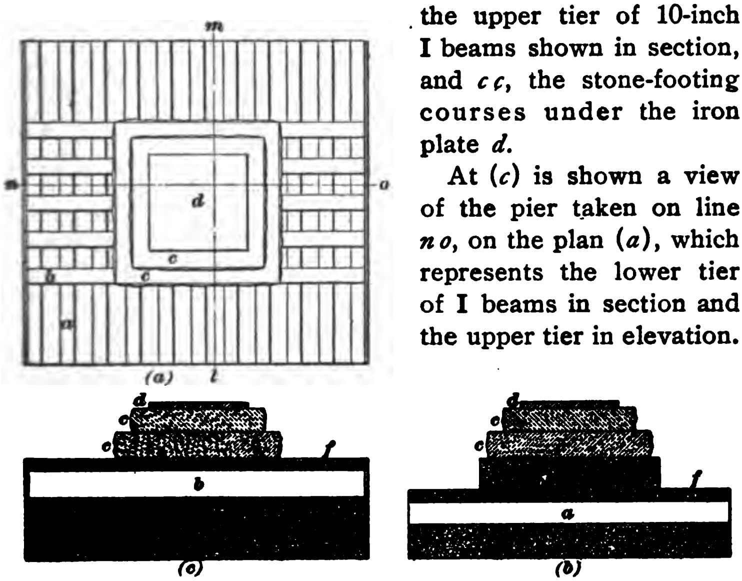


FIG. 19

The 12-inch course of concrete is shown at *e*; the lower tier of I beams at *a*; the upper tier of I beams at *b*; the concrete covering the beams at *f*; the base stones of the pier at *c c*; and the iron plate under the iron column at *d*.

30. Footings Reinforced With Steel Rails.—In some cases, iron or steel rails are used for footings, and are cheaper than I beams. The footings are built up with from three to six layers of rails placed at right angles to one another. As each layer of rails is laid, concrete is filled between and around them.

Fig. 20 shows a footing built in this manner. At *a* is shown the steel or iron rails with concrete between them; *b* is the base stone supporting the brick pier *c*; while *e* is a bond stone in the pier, and *d* is the concrete base. In this case, each layer of rails diminishes in length and number until the area of the top layer does not greatly exceed the size of the pier base, the footing thus assuming a pyramidal form.

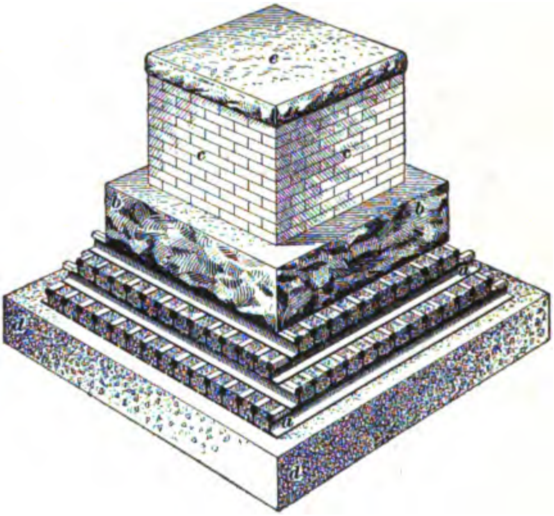


Fig. 20

SPECIAL FOOTINGS

FOOTINGS ON PILE

31. Timber Footings on Piles.—For footing courses on pile foundations, several methods are employed. Fig. 21 shows a timber footing course, or capping, laid below the water level to prevent rotting. The piles *a* are cut off to an even height, and on these the heavy timbers shown at *b* are spiked longitudinally, and on top of the longitudinal timbers, the timbers *c* are laid transversely and are secured to the first course on the piles.

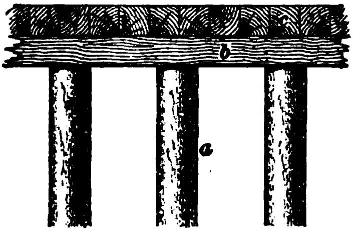


Fig. 21

By this method, the loading is distributed evenly over the top of the piles.

32. Stone Footings on Piles.—Fig. 22 illustrates footings made of large-sized building stone with level beds. At *a* are shown the piles and at *b* the building-stone footings. These stones must in every case rest directly on the piles. Great care must also be taken that one pile comes under each corner of the stone, to keep it from tipping, and that the stone has a full bearing on each pile head. To insure this, the piles must be sawed off perfectly level and all the same height, as no pieces of wood or small bits of stone should be placed under the stone footings to give them bearing on the piles. Wooden chips crush under a load, and pieces of stone are likely to be broken or dislodged, leaving the block in a state of dangerous instability.

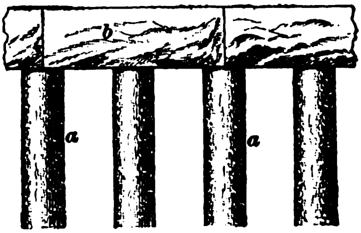


FIG. 22

33. In many cases, concrete filling is used between the piles, as shown in Fig. 23. After the piles are cut off at the water level, which is shown at *a e*, the earth is excavated to *b f*, usually about 2 feet, and the space thus obtained is filled in with concrete *c c*, well rammed around the sides of the piles *d*, *d*, and leveled off at the top to carry the

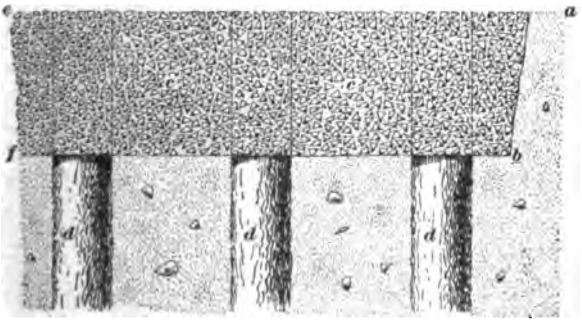


FIG. 23

foundation walls. This method is best adapted to situations where the soil is constantly wet, as then the piles will not become dry and rot. In some instances, the piles are planked over with 3-inch planking, laid transversely on top of the concrete, and on this foundation walls are built.

34. Cluster Piles With Brick Arches.—Piles are sometimes driven in groups, and the building is carried on arches sprung from one group, or cluster of piles, to another. Fig. 24 shows one form of this method of construction that has been successfully used on alluvial soil.

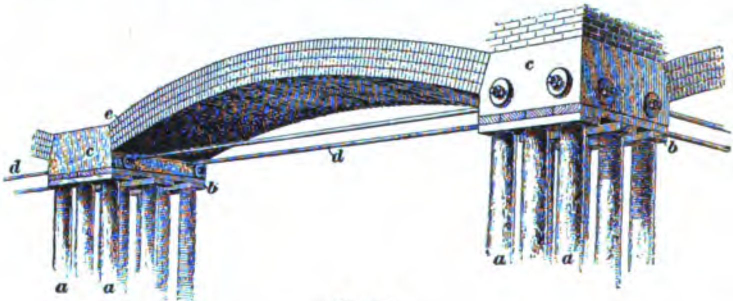


Fig. 24

The pile shown at *a*, *a* are driven in groups of nine. They average 20 feet in length and are driven until they sink about 1 inch at the last blow of a hammer weighing 1,200 pounds. On the piling, 3″ × 12″ planks are laid transversely and longitudinally, spiked to the top of the piling, as shown at *b*, *b*. The stone skew backs *c*, *c* are placed on this planking, and tied together with $1\frac{3}{4}$-inch tie-rods *d*, *d*. The brick segmental arch *e* is then sprung between the skew backs. This arch is laid up in four courses, or rowlocks, of brick. The brickwork is 24 inches thick up to the level of the water-table of the building.

CRIBS, OR CAISSONS

35. A **caisson** is a chamber of iron or wood used in the construction of deep foundations. Formerly, caissons were used exclusively for the foundations of bridge piers, but the advent of steel skeleton construction and consequent erection of very tall buildings have caused caissons to be used for building foundations.

36. There are two methods of reaching the required foundation.

In the first method, the desired depth is reached by excavating the material from the interior of a large timber or iron box, or cylinder, strongly constructed for the purpose, and then forcing the structure to sink until the required depth is reached by placing a sufficient weight or load in it. Structures of this kind are called **open caissons,** or **open cribs.**

The second method is used when the foundations are to be carried to a great depth in very soft material or in water. The lower part of the caisson is formed into an air chamber resting on the soil at the bottom. Air is pumped into this at a pressure corresponding to the depth below the surface, and the excavation is carried on by men working at the bottom, as in a large diving-bell. Such a structure is called a **pneumatic caisson.**

After the crib, or caisson, is sunk to the proper level, either to rock or compact gravel, the inside space is filled with concrete; on this the piers or foundations are built, if the open caisson is used; and on top of the caisson itself, if the pneumatic method is used.

37. The work of sinking the cribs, or caissons, is outside of the architect's province, and is usually entrusted to some firm of engineering contractors who make a specialty of work of this description, and who leave everything in readiness to construct the foundation walls or piers.

INVERTED ARCHES

38. When a front or other wall is composed of isolated piers, it is well to combine all their footings into one, and to step the piers down, as shown in Fig. 25, in which *a* shows the concrete footing course; *b*, the stepped-up foundations of the piers; and *c*, the piers resting on the footings.

39. When there is not sufficient depth to step the foundations, use is sometimes made of **inverted arches.** These are to be avoided unless the foundation wall is from necessity very shallow, as great care is required to lay them properly, and the slightest settlement in the arches has a disastrous effect on the piers.

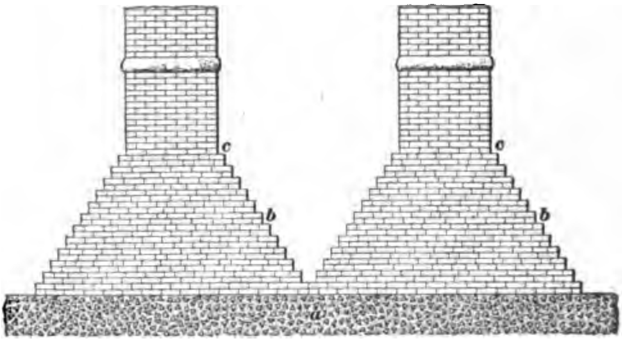


Fig. 25

The end arch of the building must have a pier or other support of sufficient weight or strength to resist the thrust of the arch; otherwise the weight might throw out the pier, as shown by the dotted lines at *a*, *a* in Fig. 26.

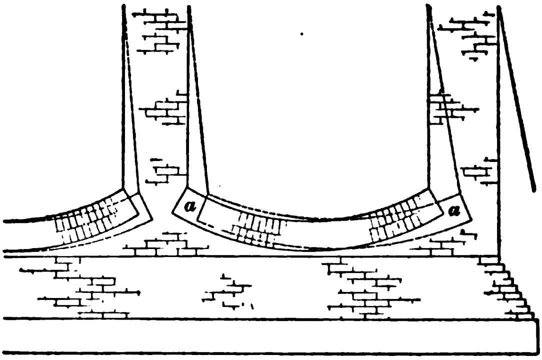


Fig. 26

This difficulty is overcome by the use of an iron rod, with iron plates and nuts, as shown in Figs. 27 and 28, thus securing the skew backs in place.

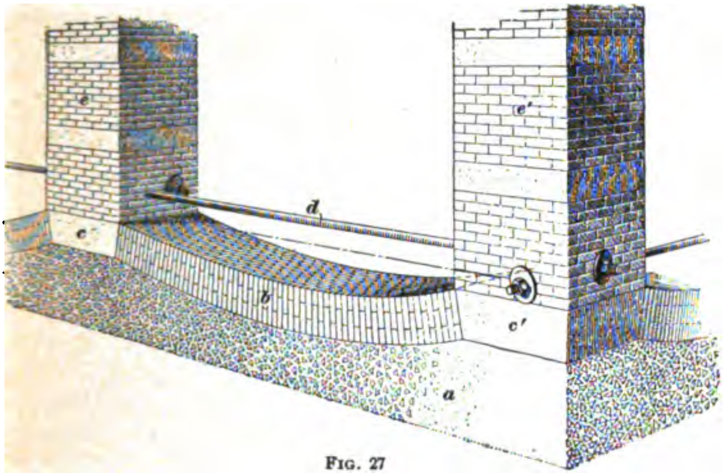


FIG. 27

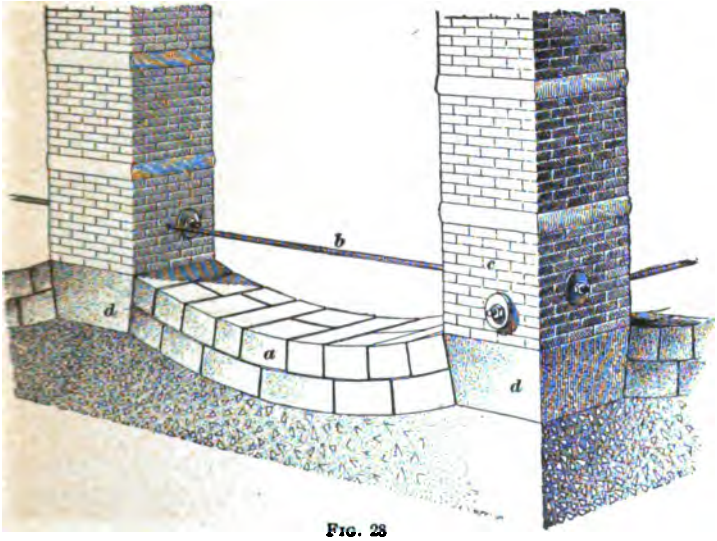


FIG. 28

The inverted arches turned between the piers should be at least 12 inches thick, the full width of the piers, and should rest on a continuous bed of concrete of proper area, and at least 18 inches in thickness; or two footing courses of large stone may be used, the bottom course to be laid as stretchers and the top course laid as headers.

40. Fig. 27 represents two piers, 3 feet square, connected by a brick-and-concrete inverted arch. At *a* is shown the 18 inches of concrete under the 12 inches of brickwork *b*. At *c*, *c'* are shown the stone skew backs from which the brick arches spring, and *d* is the 2-inch iron rod tying the end pier *e'* to the second pier *e*, and thus preventing the thrusting out of the end pier.

Fig. 28 shows an inverted arch built of stone 24 inches thick. At *a* is shown the stone arch maintained in position by the iron tie-rod *b*, and at *c* the brick foundation piers are shown on the skew backs *d*, *d*.

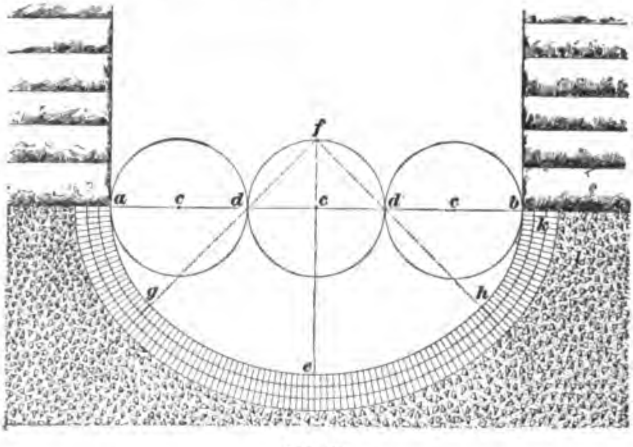


FIG. 29

41. The best form of inverted arch is the three-centered, or elliptic; next, the pointed; third, the circular; and lastly, the segmental arch.

Fig. 29 represents the method of getting the lines for the centering in an elliptic arch. Divide the space shown on the line from *a* to *b* into three equal parts, then draw the three circles *c*, *c*, *c* so that the circumferences of these circles will be tangent at *d*, *d*. Then carry the perpendicular line *e f* through the center of the middle circle; the point *f* where it intersects the circumference of the circle, gives the center of the arch from *g* to *h*. From *f* draw lines through *d*, *d* to *g* and *h*. The intersection of these lines at *d*, *d* gives the centers of the arch from *g* to *a* and from *h* to *b*. At *k* is shown the 12 inches of brick in the arch, and at *l* the concrete under it. This form of arch is used frequently in the construction of sewers.

DESIGN OF FOOTINGS

PROPORTIONING FOOTINGS

42. It is very important that the foundations, whether continuous, as in a foundation wall, or isolated, as when divided into piers, should have the footing courses proportioned to the weight they will be required to carry, and to the bearing capacity of the soil. The weight the footings must carry is divided into several classes or loads. There is, for instance, the **dead load**, due to the weight of the materials of which the building is made, and the **live load**, due to the weight of furniture, occupants, goods in storage, etc. There is also the *snow load* and *wind load*, which are of less importance.

The pressure on the soil from each square foot of the footings should be the same, where the soil is uniform, and at no place must the safe bearing power of the soil be exceeded. To secure the most satisfactory results, therefore, the footings must be proportioned to properly distribute the weight they are to carry over a sufficient area of ground, to secure uniform settlement in each case. If these conditions are always properly considered, there will be few cracks in the mason work, as such cracks are caused usually by unequal settlement. A uniform settlement even of an inch or more will in most buildings pass unnoticed.

43. Fig. 30 (*a*) shows a tower with a continuous foundation. It will be seen that the masonry of the walls does not bear down on the foundations under the door, but only at the piers at both sides of the door, as indicated by the two downward-pointing arrows. The foundation at these two points has to carry a greater load than the foundation in the middle and will therefore settle more, causing the wall above to crack, as shown. To obviate this, the foundation should be built of isolated footings, as shown in Fig. 30 (*b*). In this case, the walls will settle evenly at all points and the masonry will not crack. Of course, for houses light in weight, with small doors, this precaution need not be taken, but in building a heavy tower on yielding soil, as shown, it is of importance. Almost all the high office buildings in Chicago are built on isolated footings as shown in Fig. 30 (*b*).

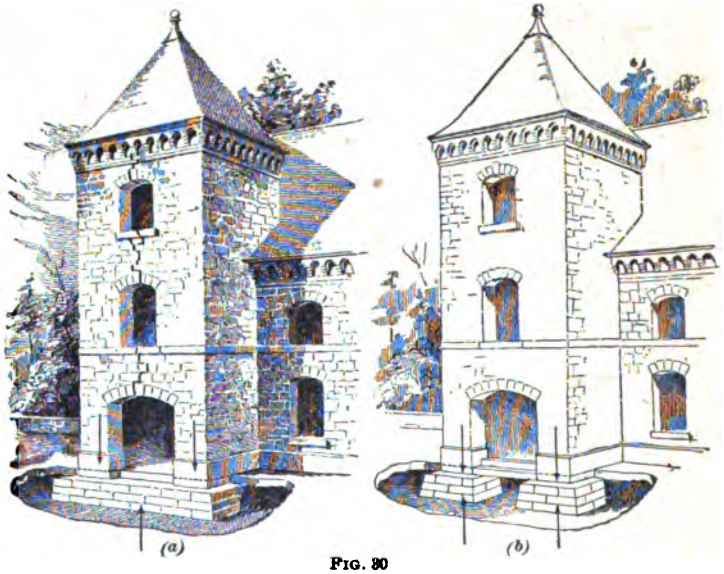


FIG. 30

44. In order to proportion the area of the footings in buildings with continuous outside foundations, the weights coming on each inside pier, and the weight of, and loads carried by, all the walls should be computed, and entered in a memorandum book for reference. The ground should be examined, and the load per square foot that it is deemed advisable for the footings to carry should be determined (see table in *Excavating, Shoring, and Piling* for bearing power of different soils). The load on the various footings divided by this unit load will give, as results, the proper area of each in square feet.

45. Where the exterior walls of a building are the support for the floors and are of masonry, it is customary, in designing the footings under the cast-iron or steel columns in the interior of the building, to so proportion them that they will exert a unit pressure on the soil 10 per cent. greater than the pressure exerted by the footings under the walls. This is done so that the greater settlement of the soil under the columns will compensate for the settlement that will take place in the body of the masonry, owing to the shrinkage of the mortar joints. However, this condition does not exist to so great an extent when cement mortar is used.

46. One object of proportioning footings, as has been stated, is that the building shall settle evenly without cracking the masonry. In order to obtain this result, the footings must be proportioned according to the *average load* they will carry and not to the *greatest load*, although, of course, they must be sufficiently large to safely support any weight that is likely to come on them. That is, the live load that would actually exist in the building should be considered, and not the maximum live load that might be—but probably never would be—applied to all the floors at one time. If the maximum live load were used, the footings under piers, which support a very large floor area compared with those under the walls, would be so large that the settlement would be very little compared with that of the footings under walls, and, consequently, cracks would occur. If the average load that the building will carry is used, the settlement will be uniform; but in proportioning the footings, for this average load, a smaller bearing value of the soil should be used so that the footings will be large enough to support the maximum load if it should ever be applied.

The Chicago building law says, "Foundations shall be proportioned to the actual average loads they will have to carry in the completed and occupied building, and not to the theoretical or occasional loads."

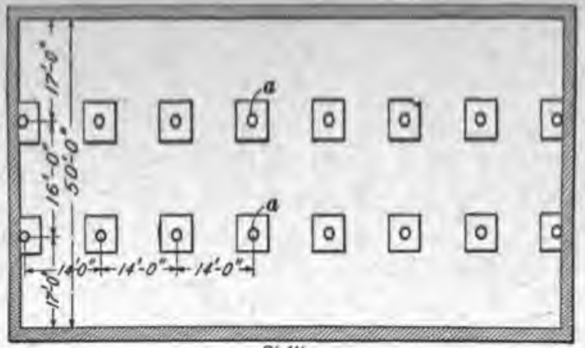
Care must be taken, however, when proportioning footings to the average load, that the maximum load per square foot on a footing does not exceed the allowable safe bearing value of the soil.

47. For warehouses, stores, etc., 50 per cent. of the live load (the load due to the weight of the contents of the building, but not of the building itself) that the floorbeams have to carry should be added to the dead load carried on the footings. For office buildings, hotels, dwelling houses, etc., the weight of the people occupying them need not enter into the calculations for proportions of footings, and only from 25 to 30 pounds per square foot of floor need be allowed for the weight of furniture, books, safes, etc. Statistics prove that the average permanent loads do not exceed the limits just stated. For theaters, halls, etc., a larger allowance should be made for the weight of people, but even a densely packed crowd of men will not weigh more than 150 pounds per square foot of floor.

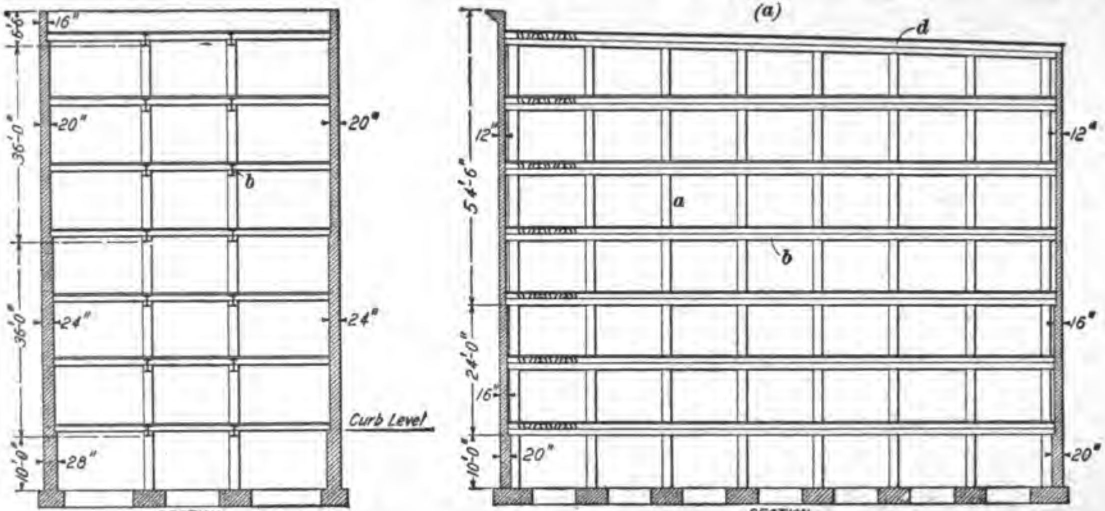
CALCULATING AREA OF FOOTINGS

48. Fig. 31 represents a building the footings of which are to be proportioned. At (*a*) is shown the plan; at (*b*), the longitudinal section; and at (*c*), the transverse section of a six-story warehouse and its basement or cellar, built on ordinary dry clay in a thick bed. The building is 50 feet wide, with a double row of longitudinal columns *a a* supporting iron girders *b*.

The load on 1 lineal foot of the side walls will be about 164 cubic feet of brickwork, weighing about 19,680 pounds, at 120 pounds per cubic foot. One foot of wall has to



PLAN
(a)



SECTION
(c)

SECTION
(b)

Fig. 31

support $8\frac{1}{2}$ square feet of each floor and the same amount of roof area. This area can be calculated from the plan (*a*).

The floors are assumed to be constructed of steel beams filled in between with hollow terra-cotta tile, with cement filling on top. This floor will weigh, altogether, 75 pounds to each square foot of surface. The roof, shown at *d*, Fig. 29 (*b*), is also of fireproof construction, but has lighter steel beams, and weighs 60 pounds to the square foot. Thus, the dead load from the six floors and the roof would amount to

$$8.5\,(6 \times 75 + 60) = 4{,}335 \text{ pounds}$$

The first, second, and third floors are supposed to carry 150 pounds to the square foot, and the fourth, fifth, and sixth floors, 100 pounds per square foot, the weight of snow on the roof being taken as 12 pounds per square foot. Then the total live load on the footings amounts to

$$8.5\,(3 \times 150 + 3 \times 100 + 12) = 6{,}477 \text{ pounds per square foot}$$

If the wall, floor, and half of the live load are added, it will amount to

$$19{,}680 + 4{,}335 + \frac{6{,}477}{2} = 27{,}254 \text{ pounds}$$

which is the weight per lineal foot of wall that the footing must be proportioned to carry. The soil can carry a safe load of 8,000 pounds per square foot, according to *Excavating, Shoring, and Piling.*

In this calculation, only one-half the live load has been considered. This was done so that the building would settle evenly without cracking. However, on account of this, a smaller safe load for the soil must be used, say 5,000 pounds per square foot. Dividing 27,254 by 5,000, gives approximately 5 feet 6 inches as the required width of the footing.

To obtain the load on the footings under the columns, the weight of the floors and the roof, together with the live load, is calculated, the weight of the columns themselves being so little, in proportion to the other loads, that they need not be considered in the present example. Suppose that the columns are spaced 14 feet apart longitudinally and 16 feet transversely, then each column will support

14 (8 + 8½) = 231 square feet of floor; thus the dead load on the footings under the columns amounts to

$$231\,(6 \times 75 + 60) = 117{,}810 \text{ pounds}$$

and the live load is

$$231\,(3 \times 150 + 3 \times 100 + 12) = 176{,}022 \text{ pounds}$$

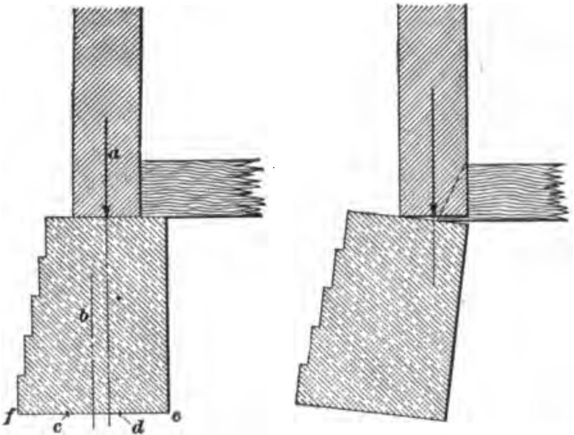
Therefore, the footing must be designed to carry

$$117{,}810 + \frac{176{,}022}{2} = 205{,}821 \text{ pounds on each pier}$$

Now, according to Art. **45**, the safe load per square foot must be 10 per cent. greater than 5,000 pounds, the figure used for the safe load per square foot for the exterior walls. Therefore, the safe load for the column bearing will be 5,500 pounds. Dividing 205,821 by 5,500 gives 37.42 square feet, say 37½ square feet. The columns in the end walls since they carry half the load each of an interior column, have each half the area of footing.

The dimensions of the front and back wall footings are easily obtained. These walls are **curtain walls**, that is, they carry no load except their own weight. The wall contains 103⅙ cubic feet of brickwork for each foot of length. Taking the weight of brickwork as 120 pounds per cubic foot, the weight of the wall per lineal foot is 103⅙ × 120 = 12,380 pounds. Dividing this weight by the safe allowable bearing of the soil, or 5,000 pounds, gives 2.48 feet, or 2 feet 6 inches for the width of the footing.

49. Besides proportioning footings, there is another consideration that must not be overlooked. The footing must have its proper location under the wall or pier. The wall or column in house building usually bears down quite evenly on the foundation; that is, the center of pressure is at, or almost at, the center of the wall, as shown by the arrow *a*, Fig. 32 (*a*). If it is not so located, it is usually due to heavy wind or cantilever loading and the problem is left to an engineer. Now, it is necessary that this line bisecting the wall should cut the base of the foundation in its middle third. That is, assume that the base of the foundation *fe*, Fig. 32 (*a*), is divided into three equal parts, *fc*, *cd*, and *de*. Now the line *a* must cut the base between *c* and *d*. If it does not, the foundation is liable to turn as shown in Fig. 32 (*b*). The center line of the bottom of the foundations is shown at *b*. It is not necessary that the lines *a* and *b* coincide, but simply that *a* cut between *c* and *d*. In fact, the foundation is usually built so that the line *b* will lie outside of *a*. This has a tendency to make the foundations tip the wall slightly inwards, so that it will press against the joists and hold tight, which is better than if the wall were allowed to tip outwards and bulge and thereby cause the ends of the joists to slip off their bearings.



(a)

(b)

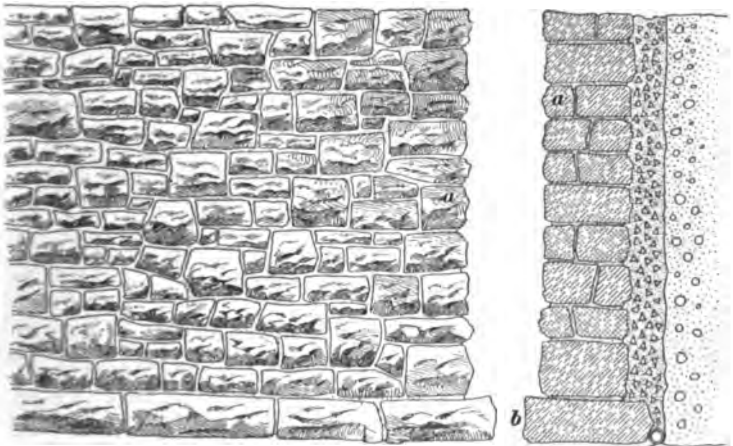
Fig. 32

FOUNDATIONS

MATERIALS AND CONSTRUCTION

STONE RUBBLE FOUNDATION WALLS

50. Stone foundation walls below ground, when concealed from outside view, are usually constructed of rough rubble, as shown in Fig. 33. This represents an elevation (*a*) and section (*b*) of a 20-inch rubble stone wall, shown at *a*, *a*, 10 feet high, with footing stones *b*, 8 inches thick, and 2 feet 8 inches wide. At *c* is shown a drain used to keep the drainage water from the surface of the wall.



(a) (b)

Fig. 33

51. Stone foundation walls should be bonded together, as shown in Fig. 34, where *a* shows the bond stone, or header. All stone walls, 24 inches or less in thickness, should have at least one header extending through the wall, every 3 feet of height and every 4 feet of length. If the stone wall is over 24 inches thick, there should be at least one header for every 6 superficial feet of wall space, running into the wall at least 2 feet. The headers should not be less than 18 inches in width and 8 inches in thickness, and should be good flat stones. These headers serve to bind the stones together in the walls, and keep the foundation from splitting apart crosswise when weight is placed on it.

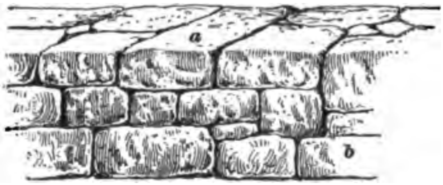


FIG. 34

52. All wall angles should be well tied by long stones laid alternately in the wall, as shown at *a a*, Fig. 35, the long angle stones tying the wall at that point. By using these long stones, the weight on the corners of the wall is more equally distributed, and the wall can be kept plumb and true.

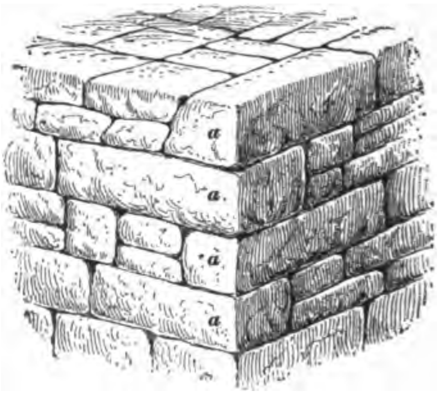


FIG. 35

53. Foundation stones should always be laid on their natural, or quarry, beds. The tendency to splitting, or cleavage, in a stone is with the grain or bed; so when the stone is laid on its original bed, the weight of the material placed above it comes against the grain of the stone. No stone should have more face than bed, and one side, at least, of each stone should be reasonably flat. Every stone laid should be well bedded in mortar.

54. The usual practice among masons in rough walling is, after setting the larger stones, to fill the interstices with

spalls, or chips, of stone, or even pebbles, more or less carefully fitted, and put in dry; then to dash in mortar, trusting that it will work its way into the crevices. It does so to some extent, but the method is not a good one. A good, conscientious workman will place no stone, even the smallest chip, except in a bed of mortar prepared to receive it, rubbing it well in, and settling it with blows of the trowel and hammer, so that all the stones have a layer of mortar between them.

A common practice is to grout the walls with mortar made so thin that it will flow into the spaces between the stone.

55. For good work, it is necessary that the outside of the wall (even when concealed by the excavated bank) should be carried up with a good face, and the joints well filled with either cement, or lime-and-cement mortar. If this is properly done, any moisture that runs out from the bank or descends from above, so as to flow down over the outer face of the wall, will drip off, instead of running into the joints.

The space between the outside of the foundation and the bank of the excavation should be filled with gravel or sand (preferably the former), well packed down. Water will then soak through this sand or gravel to the drain below; this method makes the cellar drier and warmer, and keeps much of the moisture away from the foundation walls.

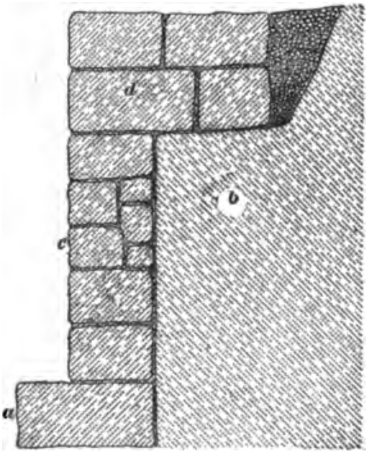


FIG. 36

FOUNDATION WALLS PARTLY ON ROCKS

56. A very faulty construction sometimes met with is that in which a portion of a ledge of rock projects into the foundation wall, and the foundation is built partly on the rock and partly on the footing course. This is shown in Fig. 36, *a* being the footing course; *b*, the rock projection into the foundation wall; *c*, the thin wall in front of the rock to bring the foundation to the thickness required in the plans; and *d*, the wall of the building carried up to its full height and thickness, and resting partly on the thin wall *c* and partly on the ledge of rock *b*.

In a wall so built, the water will find its way either through the imperceptible seams of the ledge of rock *b*, or over its top into the body of the masonry, keeping it constantly damp. Besides, there is a serious risk that under the heavy weight of the upper wall, the thin lining built up against the ledge—but in no way bonded to it—will separate from it and fall away, leaving the superincumbent masonry most insecurely supported upon the rock alone. There is, besides, the certainty that the foundation wall, built partly on unyielding rock, and partly on softer soil, will settle unequally, and crack, perhaps injuring the masonry above beyond repair, and, at least, opening an inlet for moisture.

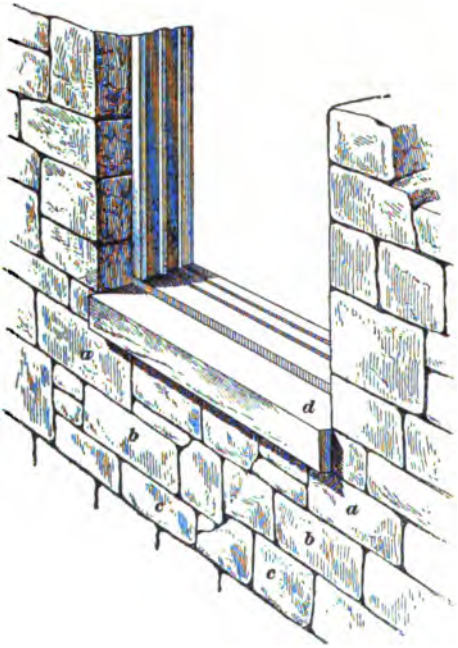


FIG. 37

The ledge should be cut away so as to leave ample space for the whole thickness of the foundation walls down to the footings, with sufficient space between the wall and the ledge of rock for packing gravel. This will intercept the water and carry it away from the wall.

OPENINGS IN FOUNDATION WALLS

57. When there are window or door openings in a foundation wall, the stones under the opening should be laid in steps, as shown at *a*, *b*, *c*, Fig. 37. This is done to spread the weight evenly under the windows. When there is to be a heavy weight on the foundation wall, the window sill should be made just the length of the opening and should not project into the wall. This allows the sill to move if there is pressure against it, and thus reduces the liability of its cracking. This style of sill is shown at *d* and is called a **slip sill.**

THICKNESS OF WALLS

58. A very good rule to fix the thickness of stone foundation walls is, that they shall be at least 8 inches thicker than the wall next above them, for a depth of 12 feet below grade or curb level; and they should be increased 4 inches in thickness below that point, for every additional 10 feet or less in depth. Thus, if the first-story walls are 12 inches thick, the stone foundation walls would have to be 20 inches thick for 12 feet in depth, and 24 inches thick below that point for 10 feet or less. Rubble-stone foundation walls are seldom made less than 18 inches in thickness. A wall

TABLE I

THICKNESS OF FOUNDATION WALLS

Height of Building	Dwellings, Hotels, Etc.		Warehouses	
	Brick Inches	Stone Inches	Brick Inches	Stone Inches
Two stories	12 to 16	20	16	20
Three stories	16	20	20	24
Four stories	20	24	24	28
Five stories	24	28	24	28
Six stories	24	28	28	32

18 inches thick is not always necessary to carry the superimposed weight, but smaller walls are more expensive to build and consequently are seldom constructed.

The thickness of foundation walls in all the large cities is controlled by the building laws. Where there are no existing laws, Table I will serve as a guide.

PROTECTION OF FOUNDATION WALLS

DAMPNESS IN CELLAR WALLS

59. Damp cellar walls are due either to water soaking through from the outside or to wet soil underneath, from which water rises in the walls by **capillary attraction.** That is, the water is soaked up by the stone or brick in the wall as it would be by a sponge. This action is increased by vertical joints in the materials of which the wall is made. The effect of capillary attraction is shown in Fig. 38, which illustrates a corner in a stone wall. This effect is more noticeable in corners than in a straight wall and more in brick than in stone.

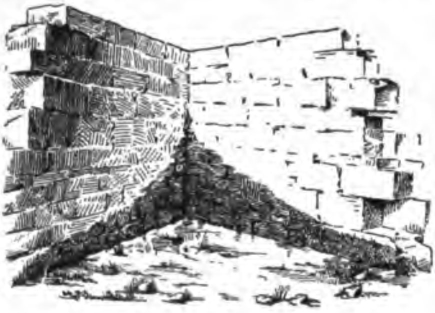


Fig. 38

WATER-TABLES

60. To avoid absorption of water by capillary attraction, which in time will stain the wall, a water-table is frequently put in just above the ground line. A **water-table** is a belt course of stone that consists of slabs of the full width of the wall. Sometimes, instead of a water-table, a course of slate is placed in the wall, as shown in Fig. 39. This will be found cheaper than the usual water-table.

DAMP-PROOFING CELLAR WALLS

61. Moisture can be prevented from entering foundation walls either by the application of cement or asphalt to the outside of the walls, by means of drainage, or by building areas around the foundation.

If only surface water has to be guarded against, cement or asphalt placed on the outside of the cellar wall is usually found sufficient. It is often specified that foundations shall be cemented on the outside, from the footing to the baseboards of a frame house, or to the stone water-table of a brick house. When it is not desired that the cement should show above ground, it is usually stopped from 4 to 6 inches below the grade line.

Boiling-hot asphalt applied to the outside of a wall is generally considered to be the most lasting and durable of all coatings. Its color, however, does not harmonize with either brickwork or stonework, hence it is usually put on below the ground level or on the inside of cellar walls. When asphalt is applied, it is necessary to have the wall built as carefully as possible, with the joints well pointed; also, the wall must be thoroughly dry before the coating is applied. The wall should have at least two coats of asphalt carried down to the bottom of the footings.

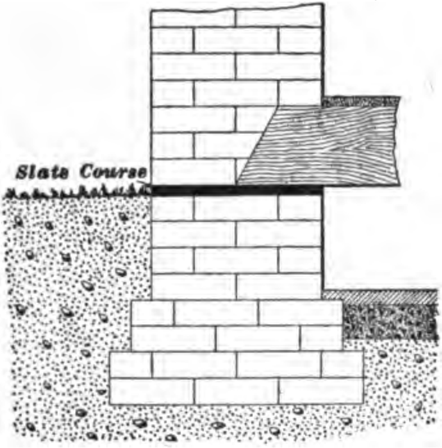


FIG. 39

62. Some clay soils, though sufficiently solid to support the walls of dwelling houses, still retain moisture in wet seasons that is not carried away into the earth, but rises in the cellar, keeping it almost always damp. Fig. 40 shows a method of damp-proofing a cellar bottom and walls that has proved successful. The cellar is first prepared by laying 3 or 4 inches of sand, shown at *a*, which is to be rolled down firm and even. Around the cellar walls, shallow gutters *b* are made in the sand, and a coating of cement *c*, 1½ to 2 inches thick, is laid over the whole surface of the cellar, with due care that sufficient slope is given to carry the water to the drain. When the cement is thoroughly dry, it is given a coat of asphalt, shown at *d*, over the entire surface of the floor, and through the walls at *e*, then up the outside of the wall at *f*, to the earth line or just below it.

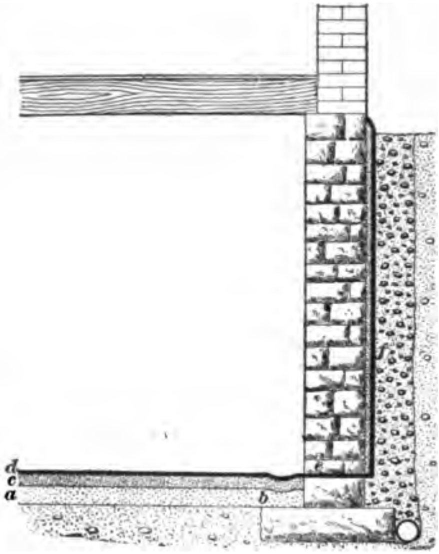


Fig. 40

Another method of securing a dry cellar is shown in Fig. 41. The cellar bottom is leveled up smooth

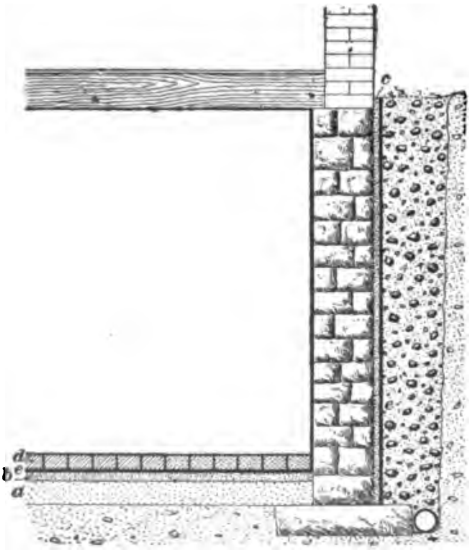


Fig. 41

and even, spread with sand, as shown at *a*, to the depth of 4 or 5 inches, and well packed with a rammer to make it firm and hard. It is better to have the sand damp, as it packs better. On top of this, the whole surface is covered with 1½ inches of Rosendale or Portland cement *b*, which is carried well against the walls. The outside of the walls is then coated 1 inch thick with cement *c*, which is carried up to the ground line. When this is dry, the cellar bottom and walls inside and outside, are covered with hot asphalt, as shown at *e*. A pavement of good, even, hard-burned, brick, dipped in asphalt, is then laid over the entire cellar as shown at *d*.

63. When the cellar floor is only moderately damp, and there is no additional moisture after rains, a good bottom may be prepared by covering the cellar bottom with mortar composed of six parts of sand, and one part each of cement and lime. On this are laid 6″ × 6″ sleepers, preferably of locust, and the spaces between the sleepers are filled in with concrete. On this the wooden flooring is laid.

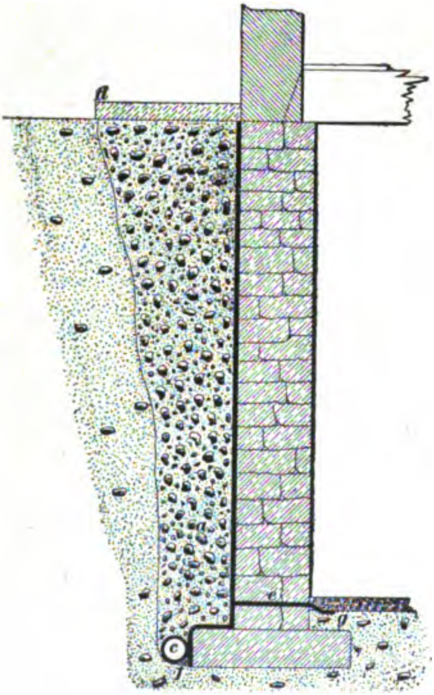


FIG. 42

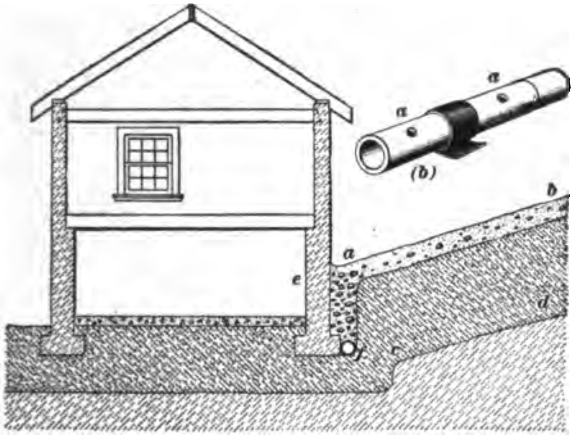
SUBSOIL DRAINS

64. A simple method of excluding moisture from cellars is shown in Fig. 42. The excavation *a* is made wider than the building, so that there will be about 1 foot of space left between the bank and the foundation wall. A tile drain, shown at *c* should be placed at the bottom of this trench and connected with a horizontal drain, emptying either into a cesspool or a sewer. The trench *a* should then be filled with loose stone, coarse gravel, and sand. If the top, for about 2 or 3 feet from the building, is then covered with stone flagging or cement *d*, it will assist greatly in keeping the walls dry. If the soil around the building is drained in this way, and the wall is coated with asphalt as shown at *e e*, a perfectly dry wall can be obtained. The asphalt should be carried down to the bottom of the footings, as at *f*, and through the wall to the under side of the cellar floor, as seen at *g*.

65. A durable composition for a cellar bottom is made of six parts of asphalt, one part of coal tar, and three parts of sand. It should be used while hot. Cement and asphalt in equal parts are also used and found durable for cellar bottoms. The ingredients should be placed over a fire in a large pan or boiler and thoroughly mixed, after which the composition should be spread over the surface.

66. One of the dangers that may be encountered during excavation is the presence of a clay bank between limestone, sandstone, or sand beds. These beds being water-tight, that is, not permitting rain water to penetrate their thickness, currents, or sheets, of water flow over them, which may cause great damage to the foundations, especially if this clay bank, or stratum, abuts against the foundation walls. Rain that will easily penetrate the gravel or loam above, or percolate through crevices of the rock, will be arrested by this clay bank; little by little it will form cavities and produce a concealed current. If the cellar wall extends below this current, the water will penetrate it and fill the cellar.

In this case, it will be necessary to turn aside this sheet of water by means of a drain, as shown in Fig. 43 (*a*). Here *a b* is the gravel, sand, or loam bed that water can penetrate; *c d*, the clay bed on top of which water collects after every rain storm, which would be stopped by the foundation of the cellar *e*, and would soon penetrate it; *f* is the transverse drain with openings upwards to receive the water, thus leaving the wall *e* dry. Fig. 43 (*b*) shows a view of part of the intercepting drain; *a*, *a* are openings for the water to enter.



(*a*)

Fig. 43

67. If foundations are laid in open clay, another difficulty is often encountered and must be guarded against. Clay banks may slip, when their slopes present such a sec-

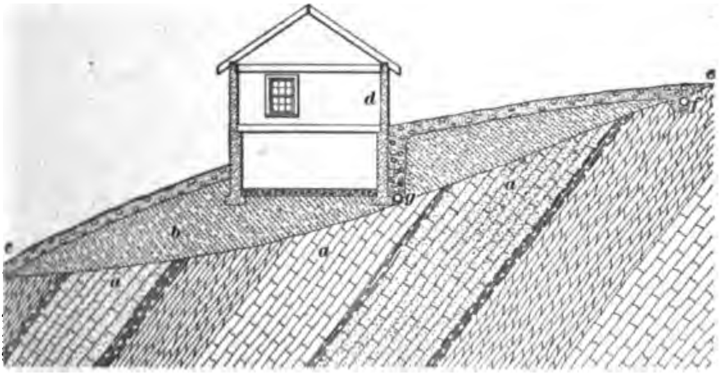


Fig. 44

tion as shown in Fig. 44, where *a a* shows the rock bed under the clay bank, or stratum, *b*, and *c* is the gravel or loam on top of the clay. The rain water accumulating above will pass at *e* under this bank, and if the rain continues long it will form from *e* to *c* a thick, soapy bed so that the clay bank may slip by its own weight, especially if that weight is increased by that of the building *d*.

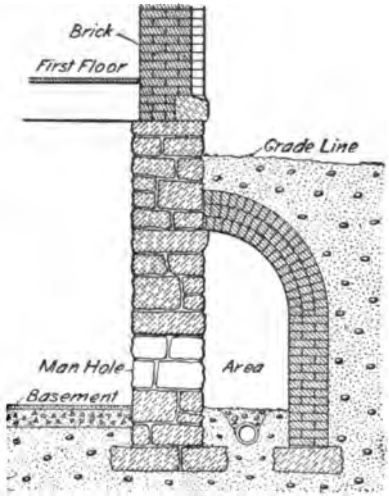


Fig. 45

This danger may be averted by building the drain *f* at the upper end of the clay bank *ce*, to intercept the water running between the clay bank and the ledge of rock. It would be well also to extend the foundation wall at *d* down to the rock, thus presenting a solid face to the pressure of the clay bank, and preventing absolutely the upheaval of the cellar floor and bulging of the wall *d*. Another drain must be placed at *g*, to intercept the water flowing through the upper strata of soil and keep the foundation walls dry.

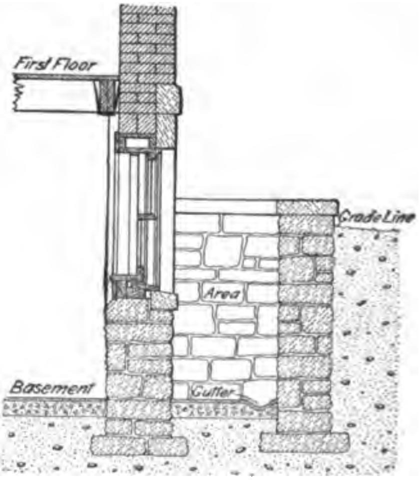


Fig. 46

AREAS FOR KEEPING CELLARS DRY

68. Fig. 45 shows one form of area used for keeping cellar walls dry. The area wall is arched to meet the building wall, as shown in the figure. Any water from the eaves of the roof is thus prevented from soaking into the ground near the cellar. This style of area wall is quite expensive to build and is used only in first-class work.

Fig. 46 shows an area wall of more common form. This style of area, although not necessarily as deep as the one shown in the illustration, is often used to admit light to the cellar windows. An area wall can sometimes be used to advantage when a building is located in a sloping clay bed.

AREAS, VAULTS, AND RETAINING WALLS

AREAS, VAULTS, RETAINING WALLS, AND PAVEMENTS

AREAS

1. Area Walls.—It often becomes necessary to excavate trenches called **areas** outside of the foundation walls of a building for the purpose of lighting or to give access to the basement, and in some cases, to keep the outside of the cellar wall dry. In order to keep the bank of earth from caving in, and to present a neat appearance on the inside, areas require a surrounding wall. Stone walls, when the joints are damp, offer greater resistance to sliding on the bed than do brick walls; hence, area walls are usually built of stone.

2. An area wall should be built strong enough to withstand the pressure of the earth back of it. For this reason, when putting in such a wall, it is best not to disturb the earth behind it any more than is absolutely necessary. If possible, the space that has been excavated behind an area wall, so that the masonry can be carefully pointed on the back, should not be filled until the mortar has set, as the wall is not then so liable to be pushed out of line by reason of the stones slipping their bed joints.

3. In building area walls, cement mortar should always be employed. Lime mortar should not be used, as it rots

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by continued moisture. The beds between the stones are generally made horizontal. However, when the face of the wall is battered, the stones are sometimes laid with the beds perpendicular to this face, which makes a stronger wall. It is necessary, therefore, in such a case that the joints should be very well pointed, otherwise rain will penetrate through to the back of the wall, moistening the back filling, and subjecting it, as well as the masonry, to the action of frost. On the whole, the safest way is to make the bed joints horizontal.

4. It is customary to build the walls with plumb-sides if they are not too high. A 24-inch stone wall may be safely built to a height of 5 feet without any danger of being tipped over by the pressure of the earth back of it. In building an area wall higher than 5 feet, however, it is customary to put a batter of about 2 inches to the foot on the outside, as shown in Fig. 1. When an area wall is longer than, say, 10 feet, it may be braced by arches that spring from the main wall of the building at intervals, as shown in Fig. 2. This bracing is not necessary unless there is a liability of the wall overturning by not being of sufficient thickness.

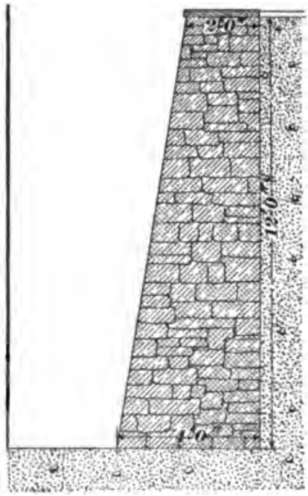


Fig. 1

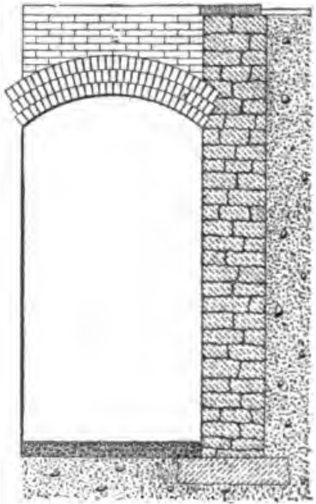


Fig. 2

5. **Coping for Area Walls.**—In finishing an area wall, or, in fact, any stonework or brickwork where there is no artificial covering, it is always best to cap the wall with a stone or tile slab that is as wide as, or a trifle wider than, the wall itself. This will insure that the least amount of injury will be done by water soaking down into the wall through the joints on the top. This top cover, or cap, on the wall is called the **coping.**

Stone coping is usually made of bluestone, granite, or some stone that will not readily absorb moisture. In cheap work, the coping on a wall is sometimes dispensed with, the top of the wall being coated with about 1 inch of Portland cement mortar instead.

6. **Area Pavement.**—Whether or not an area should be paved depends entirely on circumstances. If there is any danger of water rising up through the ground into the area, it should be both drained and paved. When an area is paved, it is necessary to provide some means of draining away the rain water. This is usually done by means of a gutter and catch basin, which should be connected to a sewer or a leaching cesspool, as circumstances permit.

7. **Window and Entrance Areas.**—Window areas should be large enough to admit plenty of light into the cellar. This fact should always be borne in mind, because, if care is not exercised, there is danger of designing the window areas too small.

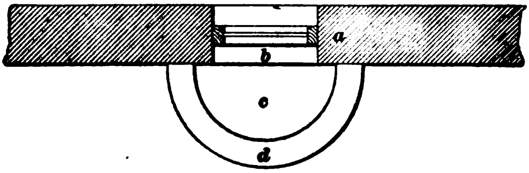


FIG. 3

Window areas are often made rectangular with side walls, which assist in bracing the area wall, but it is generally found more economical and more convenient to build them semicircular, as shown in Fig. 3. At *a* is shown the foundation wall of the building; at *b*, the window and window opening through the wall; at *c*, the area; and at *d*, the semicircular area wall, in this case an 8-inch brick wall. When the area is 3 or 4 feet deep and the same in length and width, the brick wall should be at least 12 inches thick, and if a stone wall is built, it should be 18 inches thick.

8. Drainage of Areas.—Areas should be drained in order to dispose of rain water and melted snow. To do this effectually, the bottom of the area should be made of cement mortar, laid in the proportion of one part of cement to one part of sand, or of stone flagging, or even of brick laid in cement, and should be carried about 6 inches below the window sill.

If the area is a large one, a small cesspool or sand trap, about 12 inches square, with 4½-inch brick walls laid in cement mortar should be built and connected by a drain pipe to the main drain. All open well holes and light shafts should have similar traps and drain pipes.

9. An arrangement for draining an outside area is shown in Fig. 4. At *a* is shown a cast-iron strainer, which sets

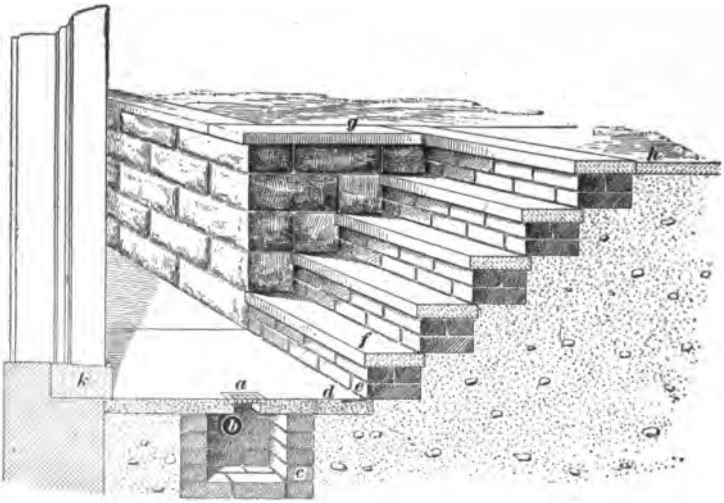


FIG. 4

over the cesspool to prevent rubbish, dead leaves, etc. from being washed into the trap and clogging up the drain pipe;

this strainer can be lifted out to remove refuse from the cesspool when necessary. At *b*, the drain pipe leaves the cesspool to connect with the main drain or sewer. At *c* is the 8-inch brick cesspool wall; the stone, brick, or cement area pavement is shown at *d*; while at *e* are shown the brick risers of the area steps. At *f* are the stone treads; at *g*, the stone coping of the area walls; *h* is the pavement; and *k*, the stone sill of the door opening into the area.

10. **Area Steps.**—Area steps should be laid in cement mortar, no lime being used. These steps should be built either of stone or of a combination of brick and stone. Concrete steps will likely become slippery if too much cement is used in making them, and are liable to wear away if too little cement is employed. However, concrete steps may be built successfully if care is taken with the work. Being *monolithic* (in one piece), they are more liable to crack than steps made of separate parts. To prevent this uncertain cracking, concrete steps are often built with *planes of least resistance;* that is, certain sections are made weaker than others by laying in the mass sheets of tar paper or other non-porous material. Then, if the steps do crack, they will part at these sheets of paper, which are so placed that the crack will appear at the angle between the riser and the tread—a place where it will hardly be noticed.

If the ground is soft or if the area is deep, the steps should have a wall on each side of them. The treads of the steps should be set in this wall at each end, in order not to have a bearing in the middle. If the risers do not rest on the treads, they should also be set in the wall. These side walls should go down into the ground below the frost line, so as not to heave up and displace the steps.

If the ground is composed of compact gravel and there is no liability of water or frost affecting it, the steps may be cut directly out of the soil. The risers in this case are generally made of two courses of brick, and the treads are made of 2-inch flags, as shown in Fig. 4.

11. On the whole, stone steps are the most satisfactory for areaways, especially when the ground is soft or the area

deep. There are two kinds of steps that may be used, either solid stone or 2- or 3-inch flags. The solid steps are the stronger, but are also more expensive. Each block of the solid steps should be laid so as to lap from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches over the step below it, as shown in Fig. 5 (*a*). There are two ways of making steps of flags, as shown in Fig. 5 (*b*) and (*c*). The method shown at (*b*) has the advantage that the risers are not so likely to be shoved out of place by the movement of the earth behind them, due to rain or frost, while the style shown at (*c*) possesses the advantages of having no vertical joints in which water may penetrate and of having the load partly transferred from one step to another. When flag steps are more than 5 feet wide, they may be supported in the middle by a stone or concrete dwarf wall.

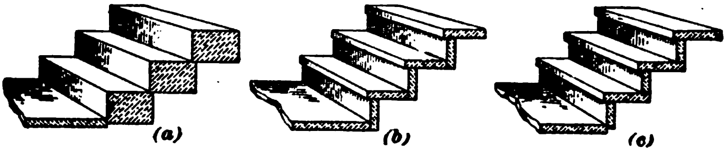


FIG. 5

12. Plank steps supported on plank string pieces are used in many localities; also iron stringers with plank treads. The ground should be excavated, and the area walled up under them. When the plank treads decay or are worn out, it is a matter of small expense to replace them. The steps should finish on a platform made of cement, flagging, or brick.

In order to shed water properly, steps of stone, wood, or any material should always slope from the rear to the front, the pitch being from $\frac{1}{8}$ to $\frac{3}{16}$ inch, according to the width of the treads.

VAULTS

13. Sidewalk Vaults.—In large cities where land is expensive, it is sometimes necessary, when building on a small lot, to use all the available space. For this reason, the cellar is often extended to the curb line and a retaining wall is built to sustain the adjacent soil. This extra space is called a **sidewalk vault.**

14. Building Laws Regarding Vaults.—In regard to sidewalk vaults and areas, the New York building laws read as follows:

> In buildings where the space under the sidewalk is utilized, a sufficient stone or brick wall, or brick arches between iron or steel beams, shall be built to retain the roadway of the street, and the side, end, or party walls of such buildings shall extend under the sidewalk, of sufficient thickness, to such wall. The roofs of all vaults shall be of incombustible material. Openings in the roofs of vaults for the admission of coal or light, or for manholes, or for any other purposes, if placed outside the area line, shall be covered with glass set in iron frames, each glass to measure not more than 16 square inches, or with iron covers having a rough surface, and rabbeted flush with the sidewalk. When any such cover is placed in any sidewalk, it shall be placed as near as practicable to the outside line of the curb. All vaults shall be thoroughly ventilated.
>
> All areas shall be properly protected with suitable railings, or covered over.

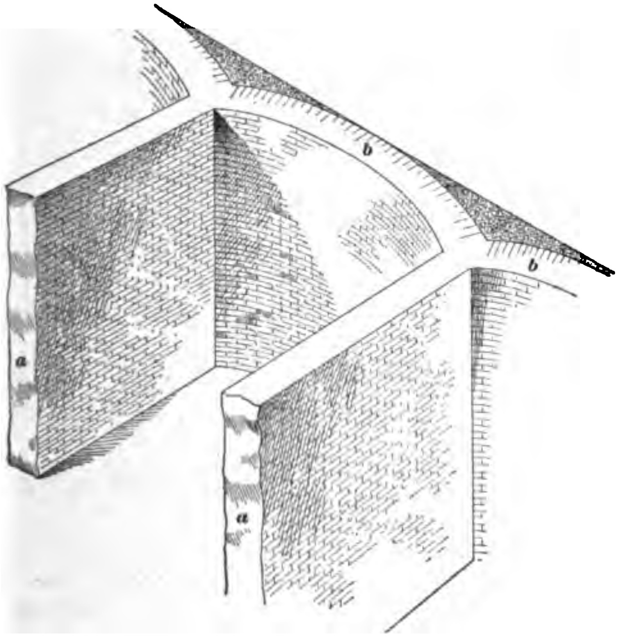


FIG. 6

> When areas are covered over, iron, or iron and glass combined, stone, or other incombustible materials shall be used, and supported on brick or stone walls, or on iron or steel beams.

15. Vault Construction.—A method of construction in use where partition walls can be placed in the sidewalk vaults is shown in Fig. 6. The partition walls *a* are spaced about every 10 feet, and are usually 12 inches thick. The outer or street wall is shown at *b*. It is built in the form of an arch, of hard brick laid in cement mortar. These arches are usually about 16 inches thick, and the rise, or height of the arch above the springing line, is one-sixth of the span.

16. When it is desired to have the vault unobstructed by partitions, each sidewalk slab may be supported by an I-beam column, as shown in Fig. 7. In this method of construction, the iron columns *a* support the outer ends of the I beams *b*, which carry the stone flag or concrete pavement, shown at *c*. The space between the I beams is filled with fireproof blocks *d*. The curbstone is shown at *e*; when bluestone or granite flags are used, they are usually carried out to the gutter line and projected over the curbstone, or, if sufficiently thick, the curbstone is omitted. The wall between the columns is indicated at *f*, and *g* is the concrete base on which the columns rest.

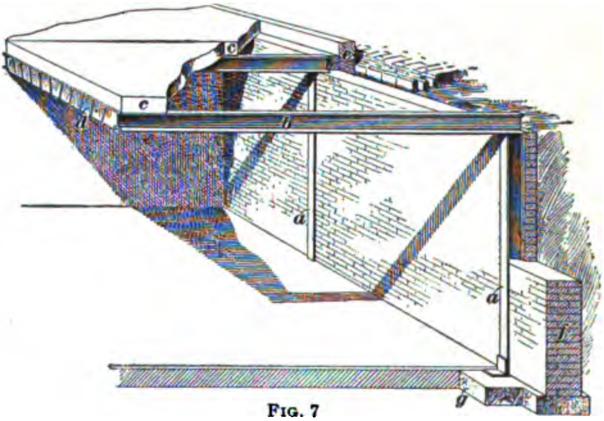


FIG. 7

17. Another method of construction, shown in Fig. 8, is used in large cities, where the vault requires light from above. At *a* is shown the area vault covered with thick glass in iron frames, known as *vault lights;* *b* is the longitudinal **I** beam that rests on the iron columns *c* and is bolted to the sidewalk girders *d*; *e* shows the flag or concrete sidewalk; *f*, the wall at the curb line carrying the ends of the sidewalk beams. This wall is shown in the illustration as built

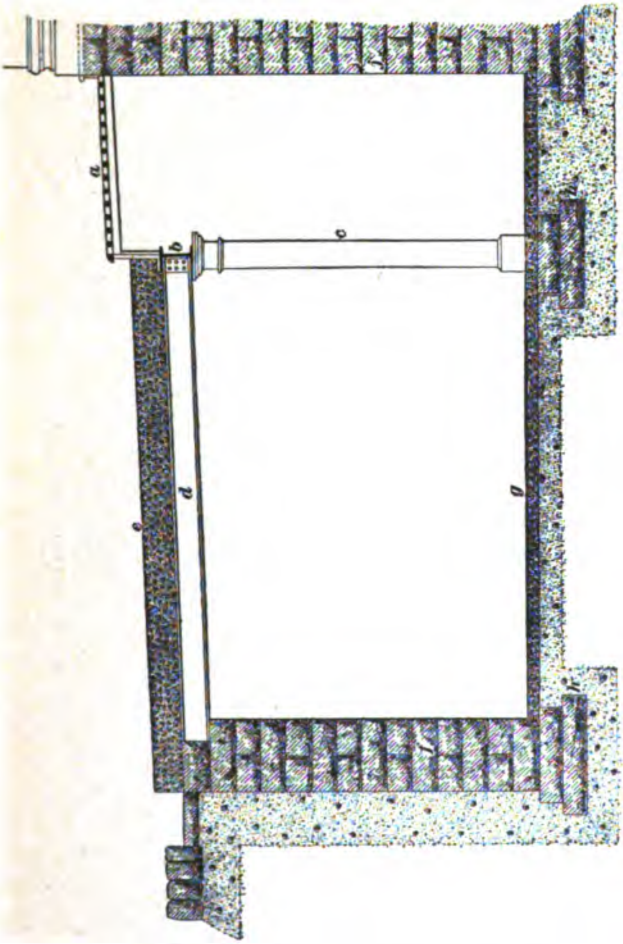


FIG. 8

of stone, but brick is often used; both stone and brick should always be laid in cement mortar. At *g* is shown the floor of the vault, usually made of 3 inches of concrete, covered with 1 inch of Portland cement mortar, made in the proportion of 1 of cement to 1 of sand; *h h* show the footings under the sidewalk wall and under the iron column carrying the area I beam; and *j* shows the foundation wall of the building.

18. Sidewalk vaults may be arched over with either brick or hollow tile; the top of the arch is leveled off with sand, cinders, or concrete, preferably the latter, and the sidewalk is laid on this; or a sidewalk made of large stone flags may form the roof of the vault. The best stone for this purpose is bluestone flag, though any compact limestone will answer the purpose. Granite is also used, but wears so smooth as to be objectionable in winter. The joints of the stone are closely fitted, and often rabbeted; then they are calked with oakum, which is forced in, to within about 2 inches of the top, and the remaining space is filled with hot asphalt or asphaltic cement. The joints will require cleaning out and refilling every few years if they are to be kept water-tight.

If brick or terra-cotta arches are used, and a brick pavement is laid on them in sand, the top of the arch should be coated with hot asphalt.

19. Vaults are sometimes extended out beyond the curb line, under the street. This arrangement does not differ from that shown in Fig. 8, except that another line of columns and girders is placed under the curb line.

Sidewalk vaults are sometimes carried 25 feet below the curb lines, and have two stories under the sidewalk, but the construction does not differ materially from that already described. In most of the large cities, special permits are required for vaults of this character.

20. Calculating Stone Flagging for Vault Covers. When the thickness of the stone flagging and the distance between the supports are given, the breaking load for a slab 12 inches wide can be calculated by the following formulas:

Let d = thickness of stone, in inches;
l = distance between bearings, in feet;
A = coefficient from Table I;
W = breaking load at center of span, in pounds;
W' = total breaking load uniformly distributed over span, in pounds.

Then,

$$W = \frac{A d^2}{l} \qquad (1)$$

$$W' = \frac{2 A d^2}{l} \qquad (2)$$

TABLE I

VALUE OF COEFFICIENT *A*

Material	Value of Coefficient *A* Pounds
Slate	3,300
Glass	2,000
Bluestone flagging	1,500
Marble, white, Italian	1,392
Marble, white, Vermont	1,236
Marble, gray, Vermont	840
Granite, Quincy, Mass.	1,200
Freestone, Little Falls, N. Y. . . .	1,152
Freestone, Belleville, N. J.	960
Freestone, Connecticut	624
Freestone, Dorchester, Mass. . . .	528
Freestone, Hubeginy	432
Freestone, Caen, Normandy	300
Limestone	1,000
Sandstone	720
Brick, pressed, American	480
Brick, common	240
Concrete, Portland, 1 year old . . .	390
Concrete, Portland, 1 month old . .	360

These formulas are expressed in words by the following rule:

Rule.—*Multiply together the square of the thickness, expressed in inches, and the proper coefficient from Table I, and divide by the span, in feet; the quotient will be the breaking load at the center for a slab 12 inches wide; and the quotient multiplied by 2 will be the total breaking load if uniformly distributed.*

The allowable load should not exceed one-tenth of the breaking load. The second formula is more often used than the first.

Table I gives the value, in pounds, of A in the foregoing formulas.

As an illustration of the use of the formulas, for example, Quincy granite, 6 inches thick, resting on supports 5 feet 6 inches in the clear, would break under a load, resting midway between the supports, equal to

$$W = \frac{1{,}200 \times 6^2}{5.5} = 7{,}855 \text{ pounds}$$

for each foot in width; dividing this by 10, to get the safe weight, we have 7,855 ÷ 10 = 785.5 pounds. When the load is equally distributed over the flagging, it will safely carry 2 × 785.5 = 1,571.0 pounds. This load is distributed over an area 1 foot wide and 5½ feet long. Therefore, the safe load that the granite will carry per square foot is 1,571 ÷ 5.5 = 286 pounds.

RETAINING WALLS

21. When a wall has to keep in place a filled-in backing of earth, rock, or gravel, it is called a **retaining wall,** because it retains the earth in its place, and resists its natural tendency to cave in. Foundation walls also act as retaining walls, with this difference, that they support a superstructure whose weight is usually found sufficient to overcome the thrust of the earth against the wall. A true retaining wall carries itself, and also must have strength enough to resist the pressure of the earth behind it. Area walls are, to a certain extent, retaining walls; but, as has been already shown, they are usually braced by arches or cross-walls from the foundation wall, and hence do not require the same thickness as a retaining wall proper.

22. The walls of swimming tanks are really retaining walls. When the tank is full, the pressure of the water in the tank is practically balanced by the pressure of the earth on the outside; but when the tank is empty, the pressure of the earth on the outside is unbalanced and the wall is a retaining wall.

23. There are many formulas for finding the strength of retaining walls, but they all assume certain facts about the earth behind the wall—its tendency to slide, the pressure it exerts, and other conditions that may or may not be true. It can readily be seen that even the changes in the weather will have a great effect on these properties of the earth supported, which may be wet or dry, soft or frozen. Many of the formulas take no account of these changes. It seems reasonable, therefore, that a retaining wall should be proportioned like retaining walls that have been actually built and found to be efficient, rather than be designed according to a theoretical formula that is known to give results that are not exact. The proportions given hereafter are therefore taken from actual practice.

24. Stone Retaining Walls.—Fig. 9 shows a common form of retaining wall. The wall is sometimes plumb on the outside, but is often built, as shown, leaning against the bank with a batter on the outside of about one in ten. Whether the wall is plumb or inclined, the joints between the stones are generally made horizontal or inclined up from the face, as otherwise water running down the face would be liable to penetrate into the wall.

The wall should be built of good solid stones laid on their quarry beds in cement mortar.

The wall should be not less than 12 inches thick on top, and the thickness above each step should be about four-ninths the distance from that point to the top. Thus, the wall at c, Fig. 9, is 12 inches thick; at a_1, above the step, the distance from the top is 3 feet and the wall is 1 foot 4 inches (= 3 ft. × $\frac{4}{9}$) thick; at a_2, the distance from the top is 6 feet and the wall is 2 feet 8 inches thick; at a_3, the distance from the top is 9 feet and the thickness of the wall is four-ninths of 9 feet, or 4 feet; while at the base a_4, the wall, being 11 feet 3 inches high, is 5 feet thick. At *b*, *b* are shown the footings, each course being made as a rule 12 inches thick, and each course projecting at least 6 inches beyond the course above.

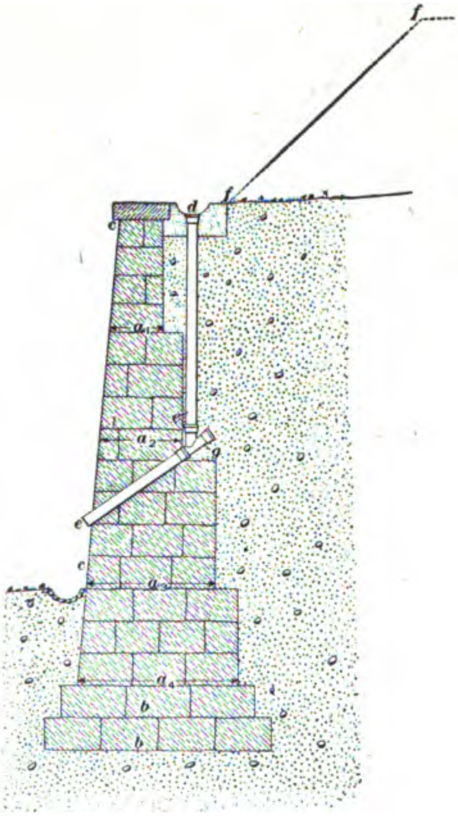


FIG. 9

The stability as well as the appearance of a retaining wall is increased by battering, or sloping, it outwards. This batter, as shown at *c*, *c*, is usually about 1 inch to the foot.

25. When the ground back of the wall slopes toward the wall, a cement gutter *d* should be formed behind the coping and connected with a drain pipe *e*, to carry off surface water that would otherwise run down behind the wall and affect its stability. Sometimes a **Y** fitting is placed at *g*, and connected with the pipe from the gutter as shown, to take water away from the back of the wall; where the backing of the wall is gravel, or a shelving clay bank with sand on top, this precaution is necessary.

26. When the earth is terraced or banked up above the wall, as shown by the dotted line *f f*, additional thickness is required. It is generally agreed that if the embankment is one-third the height of the wall, the wall should have a thickness at each step equal to one-half the distance from that point to the top. Therefore, the wall at a_2 would be 3 feet thick; at a_3, 4 feet 6 inches thick; and at a_4, 5 feet 7½ inches thick. The stability of a retaining wall is increased by stepping the wall on the back, because the steps bond the wall into material behind it, and the weight of the soil resting on the steps being added to the weight of the wall, it is not so likely to slide out at the bottom.

The footings should be carried well below the base of the wall, to insure against displacement from frost or settling. It is also well to plaster the back of the wall and the top of the steps with cement, to a depth of 3 or 4 feet from the top of the wall.

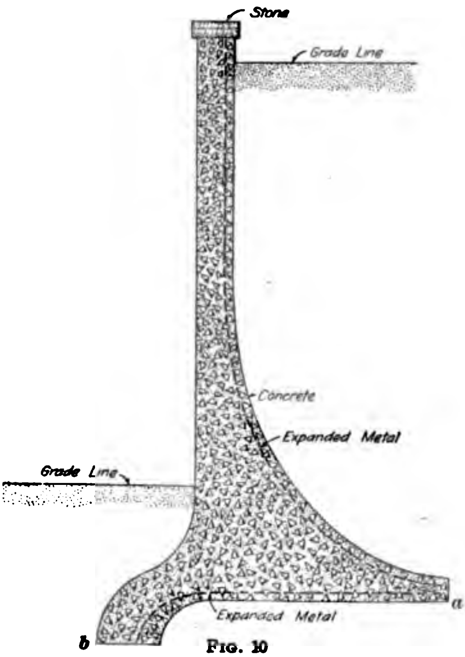


FIG. 10

27. Reinforced-Concrete Retaining Walls.—Fig. 10 shows a retaining wall built of concrete and expanded metal. A wall of this kind is able to withstand considerable pressure from the earth back of it and still be quite stable. To overturn a wall built in this manner, it would be necessary to lift the filling that rests on the part *a*, as the wall has a tendency to revolve about the point *b*. It is, therefore, evident that although the wall itself may be quite light, it borrows part of its stability from its backing, and for certain classes of work it is an economical design to use.

28. Anchored Retaining Walls.—In Fig. 11 is shown a retaining wall equipped with land ties. These ties *a* consist of wrought-iron rods 1 inch in diameter, which are anchored through the cast-iron plates *b*. The rods should pass through the plates at about two-thirds of their height from the top, and the anchor plates should be placed far enough from the retaining wall to be in solid ground that is not liable to slip. Cast-iron washers *c* are placed under the nuts of the bolts, as otherwise the nuts might pull through the wall. This method of securing a retaining wall cannot be recommended very highly, as the rods are liable to rust through and allow the wall to overturn.

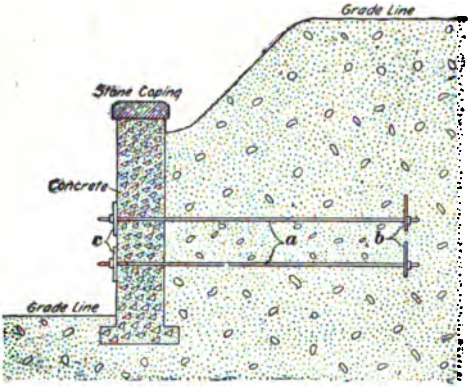
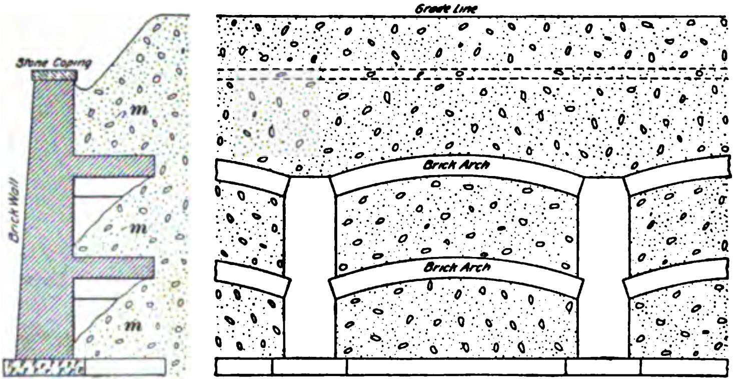


FIG. 11

29. Relieving Arches.—When great strength is required for retaining walls, relieving arches are used. Fig. 12 (*a*) shows a section through a retaining wall that is



(*a*)

FIG. 12 (*b*)

strengthened by two relieving arches; Fig. 12 (*b*) is an elevation of the arches. The wall may be reinforced by either one or two arches. The filling *m* does not press against the wall but rests on the arches as shown. This style of wall is very strong, although quite expensive to construct.

PAVEMENTS

30. Pavements may be made of flagstones, concrete, or brick. A flag is a thin slab of stone, which is generally used in pavement work. Concrete pavements are usually finished on top with cement and sand. The bricks used for pavement work should be hard and of the variety known as paving brick.

31. Stone Pavements.—If stone of a texture that readily splits into flags can be obtained, it will probably make a better and cheaper pavement than one made of concrete. A flag pavement can be taken up and relaid better than one of concrete, is easier to repair, and is also more durable.

32. The stone for pavements should be 2 or 3 inches thick when used in areas or similar places, and the flags should be cut rectangular. They should be laid on a sand bed 2 or 3 inches in thickness. The edges of the stones usually rest on a small bed of concrete, and one-to-one cement mortar is put into the cracks as shown at *c*, Fig. 13. This makes a joint that will prevent water from soaking down between the flags and freezing. In countries where

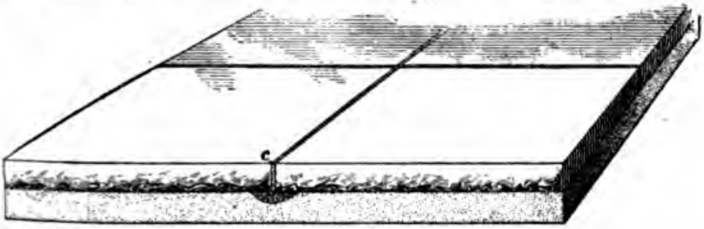


FIG. 13

there is no frost, this concrete and cement may be omitted, and the pavement may simply be laid on the sand bed.

33. Stone Sidewalks.—A stone sidewalk is laid the same as any other pavement, but owing to the fact that it is subjected to more traffic, it should be built more substantial. The flags used for sidewalks are therefore generally 3 or 4 inches thick. It is always best if possible to have the stones run all the way from the curb to the building line, but for wide sidewalks this is impracticable. When there is danger of frost getting under the sidewalk and thus causing it to heave, the flags should be supported at the ends only, as shown in Fig. 14. A 12-inch dwarf wall should be built at the curb line, as shown at *a*, and carried below the frost line. The curbstone *b* is from 4 to 6 inches thick, and is rabbeted into the dwarf wall; *c* shows the gutter, and *d* the stone pavement, which is supported at its center by a dwarf wall *e*. If the sidewalk is laid in two courses, or if it extends to the building line, it may rest on a brake in the foundation wall *f*, as shown.

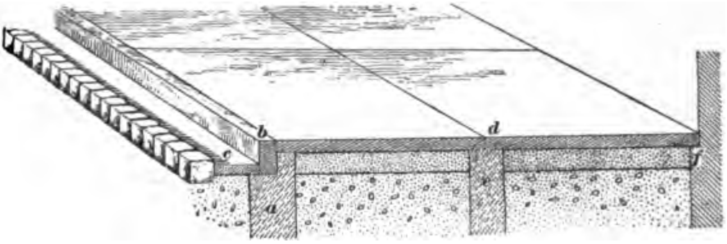


FIG. 14

34. Cement Sidewalks.—The method of laying cement sidewalks is as follows: The ground should be leveled off from 20 to 30 inches below the finished grade of the walk, and should be well settled by ramming, care being taken that the excavation is drained to one point. A foundation from about 16 to 20 inches thick should then be laid, composed of coarse gravel, stone chips, sand, coal ashes, or cinder, well tamped or rolled with a heavy roller. An attempt is often made to economize on this foundation by making it only 5 or 6 inches thick, which generally has the effect of allowing the frost to penetrate to the ground and heave up the pavement in spots.

After the foundation has been rolled, the concrete should be prepared in the proportion of one part of cement, three parts of sand, five parts of broken stone, and a sufficient quantity of water to make a stiff mortar. It should be thoroughly mixed and worked while being laid. The top, or finishing, coat should be laid immediately, and only as much concrete should be laid as can be covered with cement on the same day, for if the concrete gets dry on top, the finishing coat will not adhere to it. The top coat should be prepared by mixing one part of the best Portland cement with two parts of fine sand or two parts of clean, sharp, crushed granite or flint rock.

A ½-inch space should be left between the curb and the pavement and between the building line and the pavement, to allow for expansion and contraction. This space should be filled with cinders or ashes. The pavement itself should be laid off into blocks 6 feet square or less. These blocks should be separated from one another by sheets of tar paper, which should extend all the way through the concrete. It is very essential that grooves be made with a trowel in the top coat directly over the tar paper, so that if the concrete cracks, it will be sure to part in these grooves and not in the body of the pavement.

35. Hair cracks are often caused by the mortar in the top coat being too rich in cement. If the pavement is troweled too much, it has a tendency to make the cement float to the top, which is as liable to cause hair cracks as the use of too much cement. If the top coat is put on too wet, it has the same effect.

36. In many cities, the law requires the concrete pavements to be finished with a rough surface. Such a surface is not as slippery in winter as a smooth finish, and also possesses the additional advantages that it is easier to construct and does not show any hair cracks. In laying such a surface, the top coat is leveled with a straightedge running on battens, one set on each side of the walk. The battens are arranged so that the walk at the curb will be lower than at the building wall. (This pitch is controlled by city ordinances, and is usually 4 inches in 10 feet for all sidewalks.) The pavement is then left until it has almost set, before it is troweled. It should be troweled as little as possible and with a wooden trowel instead of one made of steel. After troweling, it should be covered with straw and kept moist for at least a week. The less the pavement is smoothed with the straightedge or trowel, and the more it is rammed instead, the better it will be.

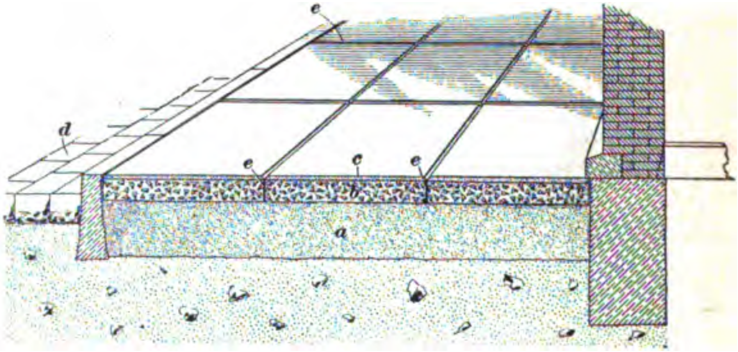


FIG. 15

Fig. 15 shows a section of a concrete pavement; *a* being the ashes or spalls; *b*, the first coat of concrete; *c*, the finishing coat; *d*, the street paving; and *e*, the joints with tar paper in them.

37. Brick Sidewalks.—In constructing brick sidewalks, good hard paving bricks, sound and square, should be used. These bricks should be laid flat, herring-bone fashion, on a bed of sand that is from 4 to 6 inches thick. After the bricks are laid and graded, the entire surface should be covered with sand, which is swept over the bricks until the joints are thoroughly filled. If extra thickness of wearing surface is desired, the bricks may be set on edge, and covered with sand as described.

CEMENTS

LIME AND CEMENTS

LIME

1. Introduction.—Any substance that is plastic at one degree of moisture or heat and tenacious at another is, in a broad sense, a **cement.** However, the word cement, as now used in building construction, means more particularly a certain one of the many varieties made from a mixture of limestone and clay. This substance has the peculiar property of *setting* (that is, getting hard) under water. For this reason, it is often called *hydraulic cement.*

2. There are many kinds of cementing materials; but those principally used for building purposes are lime and hydraulic cements, plaster of Paris, and Keene's cement.

3. Uses of Lime and Cement.—Cement, in building construction, has three principal uses: first, as a material to hold other bodies together; second, as a material with which to coat parts of structures; and third, as a building material in itself. The first use is illustrated by the mortar in the joints between stone or brick; the second, by a plastering material to coat walls; and the third, by concrete footings, walls, piers, pavements, etc.

4. Manufacture of Lime.—Lime and hydraulic cement (which hereafter will be called simply cement) are two substances that merge into each other so gradually that any distinct dividing line between them is difficult to distinguish.

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5. Lime, or quicklime, as it is sometimes called, is made from *calcium carbonate*, which is the chemical name for such substances as marble, limestone, chalk, and sea shells. The material used to make commercial lime is limestone. This stone is heated in a kiln to a temperature at which it gives off part of its constituents in the form of carbon-dioxide (carbonic-acid) gas. The lime is then ready for the builder and being put in water, it **slakes;** that is, crumbles into a powdery mass. Considerable heat is given out during the slaking. The slaked lime may then be mixed with water to form a paste, after which sand is added to make **mortar.**

6. Burning of Lime.—The best limes in this country are *wood-burned limes;* that is, those that are *calcined*, or heated in a kiln by burning wood. In Europe, on account of the scarcity of wood, the custom is to burn lime with coal. Peat also has been used with success in places where it abounds.

When lime is burned with coal, the usual method is to place the coal in direct contact with the lime. When wood is used, however, it is burned on a hearth and does not touch the limestone. This manner of burning insures a lime that is cleaner and more free from sulphur and ashes than lime burned with coal.

7. If lime is underburned, it will not slake evenly and there will be some hard pieces that will not disintegrate when water is added. If such lime is used in any work, especially for plastering walls, the unslaked particles continue to disintegrate after being incorporated in the wall, and swell or *blow*, as it is called, throwing out bits of plaster and thus injuring the surface. Overburned lime also slakes slowly, and for that reason should not be employed.

8. Properties of Lime.—If lime is stored away for some time, especially in damp weather, it will become *air-slaked;* that is, it will slake by absorbing moisture from the air. If the lime is kept in barrels for any length of time it will surely burst them, for it swells considerably when slaking.

When slaked lime is mixed with sand to make mortar, as much sand should be used as the lime will stand without injuring its adhesive quality. In important structures, where great strength is required and where the work is wanted in a hurry, lime mortar should not be employed, owing to the fact that lime shrinks when setting and lime mortar dries and sets slowly. Another reason that lime should not be used for important work is that its setting consists of nothing more than simply drying out. The outside coat does return somewhat to its original limestone form, due to the carbon dioxide absorbed from the air, but the interior portions always remain in a more or less crumbly condition.

CLASSIFICATION OF LIMES

9. Commercial lime may be divided into three general classes, namely, *rich*, or *fat*, *lime*, *poor lime*, and *hydraulic lime*. These varieties differ from one another in the amount of clay, sand, or iron they contain.

10. Fat Lime.—Fat lime is almost pure protoxide of calcium, and contains only about 5 per cent. of impurities. It has a specific gravity of 2.3 and a great affinity for water, of which it absorbs about one-quarter of its weight. This absorption is accompanied by a great rise in temperature, which is caused by the lime bursting and by the giving off of vapor. The lime finally crumbles to a powder. This powder occupies from two and one-half to three and one-half times the bulk of the original lime, the exact amount depending on its initial purity. When the lime is in this plastic state, it is said to be slaked. It is then unctuous and soft to the touch, and from this peculiarity derives the name of *fat* or *rich*.

11. Poor Lime.—Poor lime consists of from 60 to 90 per cent. of pure lime, the remainder being impurities, such as sand or other foreign matter. These impurities have no chemical action on the lime, but simply act as adulterants. Poor lime slakes more slowly and evolves less heat than fat lime. The resulting paste is also thinner and not so smooth, strongly resembling fat slaked lime mixed with sand. Poor lime is not so good for building purposes as fat lime, nor has it such extensive use.

12. Hydraulic Limes.—**Hydraulic limes** are those that contain enough quicklime to slake when water is added, and enough clay or sand to form a chemical combination when wet, thus giving them the property of setting under water.

Hydraulic limes are made from limestone containing from 5 to 30 per cent. of clay or sand. They are often considered as divided into three classes, namely, *feebly hydraulic*, *ordinarily hydraulic*, and *eminently hydraulic*, in proportion to the amount of clay and sand present. The slaking qualities of this lime vary from slaking in a few minutes after water is added, in the feebly hydraulic, to slaking only after many hours with practically no evolution of heat and without cracking or powdering, in the eminently hydraulic. The time of setting under water varies from setting as hard as soap in 20 months with the feebly hydraulic, to becoming as hard as stone in 3 or 4 days, with the eminently hydraulic. If carbonate of magnesia is present in the lime, it reduces the energy of the slaking but increases the rapidity of the setting and the ultimate strength when set.

All hydraulic limes and cements should be put in place on the work before they begin to set, because if they are disturbed during the process of hardening, they will never attain their full strength.

As the amount of clay is increased, hydraulic lime gradually merges into hydraulic cement, so that it is difficult to determine whether a material about on the border line is a lime or a cement.

CEMENT

CLASSIFICATION OF CEMENTS

13. Cements may be divided into three general classes: *Portland*, *natural*, and *puzzolan* (also called pozzuolana). These three classes of cement stand in relative importance, in the order named.

14. Portland cements are defined by the commission appointed from the Engineer Corps of the United States Army as follows: "Portland cements are products obtained from the heating or calcinating up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime by weight as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcinations, etc."

15. Natural cement is generally made by directly heating a natural cement rock to a temperature below that required for Portland cement.

16. Puzzolan cements, according to the Board just mentioned, are "products obtained by intimately and mechanically mixing, without subsequent calcination, powdered hydrates of lime with natural or artificial materials, etc."

17. The difference between these cements may be explained as follows: Portland cement is made by burning together certain proportions of such substances as limestone and clay and grinding the resulting cinder to a powder. Natural cement is made by burning, and afterwards pulverizing, a stone that has the requisite elements to make it hydraulic. Puzzolan cement is a mixture of powdered substances that have hydraulic properties in combination, without being burned together. Puzzolan cement is not used very much in the United States.

CEMENT INDUSTRY IN THE UNITED STATES

18. There is an increasing demand each year for American Portland cement, and its manufacture has assumed large proportions. In the year 1880, of the total amount of cement used in the United States, 91.8 per cent. was domestic and 8.2 per cent. was imported. Of the domestic cement. 89.9 per cent. was natural and 1.9 per cent. Portland. In the year 1900, 12.4 per cent. of the cement used in the United States was imported and the balance, 87.6 per cent., was of domestic manufacture. Of the domestic cement, the proportions had changed to 43.5 per cent. of natural and 44.1 per cent. of Portland. These figures show a large increase in the use of American Portland over natural cement. This is due to the improvement in its manufacture in this country, whereby it is now made cheaper and better than formerly.

Imported cements that are employed today in this country are used more through prejudice against American goods than through superiority of quality.

Between 1880 and 1904 the cement industry in the United States, besides changing the character of the product, increased wonderfully in extent. In the year 1880, the total consumption of cement in this country was 2,259,000 barrels; in 1904, the consumption had increased to over 25,000,000 barrels, an increase of over 1,000 per cent. No accurate figures of the cement industry are available since the latter date, but it is safe to say that more cement is used today than ever before. This increase is due to two reasons: first, the growth of the population, which demands more buildings, etc., and second, the perfection in the manufacture of cement, which brings it financially into direct competition with steel and masonry for building purposes.

MANUFACTURE OF CEMENT

19. Portland Cement.—Portland cement consists usually of from 58 to 65 per cent. of lime mixed with clay; these materials are burned together, producing a mass called a **clinker.** This clinker is ground to powder and is then ready for use.

A few years ago, the imported cements were better than any American cements on the market; but now the best American Portland cements produced are as good or even better than the best imported ones and also cost less. Portland cement is heavier, slower setting, and stronger than natural cement.

20. The so-called **calcined slag cements** are now classed, by most authorities, as Portland cement. Calcined slag cements are made of lime and slag, but are calcined by the same process as Portland cement. There is also a slag cement made without being calcined. This, of course, is classed as puzzolan.

21. **Silica, or Sand, Cement.**—Silica, or sand, cement is made by grinding together silica, or sand, and Portland cement. The sand acts as an adulterant, but on account of the extra-fine grinding of the cement, which enables it to cover more surface per unit of weight, this silica, or sand, cement is sometimes as strong as Portland cement. For the same richness of mixture, the mortar made from this kind of cement is more dense than that made from ordinary Portland cement.

22. **Natural Cement.**—A large portion of the natural cement produced in the United States is made in Rosendale, Ulster County, New York. For this reason, natural cement is sometimes called **Rosendale cement.** It weighs less than Portland, sets more quickly, but is not so strong. Natural cement contains from 20 to 40 per cent. of clay, the remainder being mostly carbonate of lime with a little carbonate of magnesia. **Roman cement** is a natural cement that is manufactured in Europe. Natural cements are cheaper than Portland cement, and are used in places where no great strength is necessary, or for the purpose of economizing.

23. **Puzzolan Cements.**—**Slag cement,** a mixture of granulated blast-furnace slag and slaked lime, is about the

only puzzolan cement found in the American markets. Puzzolan cement never reaches the same degree of hardness as Portland cement, but is tougher and not quite so brittle. It is suitable for use in wet places and will not endure long dry spells; neither will it stand wear or attrition. The original puzzolan was made from a stone of volcanic origin, found near Mount Vesuvius in Italy. The stone was ground and mixed with slaked lime. While this cement is still used in Italy, very little of it is imported to the United States.

Another puzzolan cement is manufactured from an earth called *trass*, which is also of volcanic origin. It is found in Germany and Holland. A sand called *Arénes* is also used to make puzzolan cement. Brick dust mixed with common lime will also make a feebly hydraulic cement. As has been mentioned before, slag cement when not calcined is classed as a puzzolan cement, and is in fact the most important variety in this class.

PROPERTIES OF CEMENT

24. The various kinds of cement can often be distinguished by their color and from the affinity that they have for water. Portland cement is usually gray or greenish gray. A bluish tinge indicates that it contains too much lime, while a brown color indicates too much clay. If the cement is yellowish in color, that is a sign that it is underburned. Natural cement varies in shades of brown. Slag cement is a mouse color.

If water is added, drop by drop, to a handful of Portland cement, it will absorb the water freely. If the cement absorbs the water slowly, it is, if dark, a low grade of Portland, and, if light, a puzzolan slag cement. On the whole, the detection of cements is a matter requiring considerable experience, for the foregoing tests are only true in a general way.

Portland cement weighs about 375 pounds per barrel; natural cement, about 300 pounds; and slag cement, about 340 pounds.

25. Maturing of Cement.—When cement comes from the kiln, it sometimes contains free lime. If this cement is employed on any work, the lime will continue to slake after the cement is set, which will cause cracks in the work. Therefore, cement should be *seasoned*, that is, kept for some months before being used. This will give time for any free lime to air-slake and will thus avoid subsequent trouble.

26. Setting of Cement.—A very important consideration is the time required for cement to set. This depends on a great many conditions, such as the amount of water added to the dry cement, the temperature of the atmosphere, and various other things. If the minimum amount of water is added, Portland cement will have an initial set in 2 or 3 hours and a hard set in 6 or 8 hours. Natural cement, under the same conditions, will develop an initial set in from 20 to 30 minutes and a hard set in from 40 to 60 minutes.

As will be shown by figures to be given later, cement has a tendency to get stronger and stronger for some time after it has set. It is a noticeable fact that cements that set very rapidly do not develop so much additional strength after the first month of set as do the slower-setting cements.

That cement should be put in place before it begins to set is very important. Some masons, however, have an idea that if they let the cement get an initial set and then add more water and remix it, or *retemper* it, as they say, a greater final strength will be developed than if used the proper way. This notion has been proved to be incorrect, and the practice should never be followed.

27. Various substances may be mixed with cement to make it set slowly. Among these is *sulphate of calcium* (plaster of Paris). A small addition of this material will delay considerably the setting of cement. When cement is mixed with sand, it sets slower than does the neat (pure) cement.

Whether or not cement will set when frozen is a disputed question. However, it remains undisputed that cement sets very slowly when cold, and therefore, if placed when the temperature is below freezing, it will again get soft in a few days, provided a thaw comes. Some engineers claim that natural cement will not set at all when frozen.

28. **Grinding of Cement.**—The clinker that comes from the cement kiln has no properties of setting, and will not crystallize when wet with water until after it has been ground. That the clinkers should be ground into impalpable powder, so that all portions may be active, is therefore very essential. The customary method of specifying the cement is that it shall not leave more than 20 per cent. of its weight on a screen that is made of No. 40 wire, Stubb's wire gauge, and has 10,000 openings per square inch.

In making cement mortar, enough cement should be used to completely cover each grain of sand that is employed. The finer the cement is ground, the more sand it will cover. That is another reason for thoroughly pulverizing cement.

29. **Contraction of Cement.**—When cements set in air, they contract; when they set in water, they expand. A neat cement mortar will contract more than one containing sand. At the end of 12 weeks the contraction of cement is never more than .03 of 1 per cent. In order to avoid cracks, on account of the contraction of cement when setting in air, the usual custom is to keep the work moist by constant sprinkling or by covering it with wet straw. In this way the mass can be made to set with but little contraction.

30. **Neat cement** is seldom used except for special purposes. It is sometimes used as a waterproof coat for a concrete roof or in similar places. Although not absolutely waterproof, yet it is much more so than sand-cement mortar or cement concrete. On the whole, cement is almost entirely used mixed with sand or with sand and broken stone.

31. **Strength of Cement.**—In Table I are given some figures showing the tensile strength of cement and cement mortars. These values are not exceptional, but are those that should be obtained, with good materials, in every-day practice.

TABLE I

TENSILE STRENGTH OF CEMENTS AND CEMENT MORTARS

(*Recommended by the A. S. C. E.*)

Kind of Cement	Mixture	Time Required to Set		Tensile Strength per Square Inch, in Pounds	
		In Air	In Water	Maximum	Minimum
American natural . .	Neat cement	1 hour	23 hours	80	40
American natural . .	Neat cement	1 day	6 days	100	60
American natural . .	Neat cement	1 day	27 days	150	100
American natural . .	Neat cement	1 day	364 days	400	300
American Portland .	Neat cement	1 hour	23 hours	140	100
American Portland .	Neat cement	1 day	6 days	550	250
American Portland .	Neat cement	1 day	27 days	700	350
American Portland .	Neat cement	1 day	364 days	800	450
American natural . .	1 part sand, 1 part cement	1 day	6 days	50	30
American natural . .	1 part sand, 1 part cement	1 day	27 days	80	50
American natural . .	1 part sand, 1 part cement	1 day	364 days	300	200
American Portland .	1 part cement, 3 parts sand	1 day	6 days	125	80
American Portland .	1 part cement, 3 parts sand	1 day	27 days	200	100
American Portland .	1 part cement, 3 parts sand	1 day	364 days	350	200

MISCELLANEOUS CEMENTS

32. There are a number of other materials used in architecture that can be classed as cements. Many of these, as plaster of Paris and Keene's cement, are used almost exclusively in plastering work, and will therefore be treated in another Section.

33. Bituminous Cement.—There is one cement of considerable importance, however, that should be mentioned here, namely, **bituminous cement.** It is made from bitumen and sand or stone dust. The bitumen is sometimes adulterated with coal tar. This cement has two important physical properties, being both waterproof and elastic.

Bituminous cement is largely used for street pavements, for waterproofing cellars, and for covering the extrados of arches, the tops of walls, and similar places. It is also used for the foundations of small machines placed in the top stories of tall buildings when it is desired to eliminate all vibration. The cost of bituminous cement, however, has somewhat limited its use.

CEMENTS FOR SPECIAL PURPOSES

34. Cements for Fastening Ironwork.—Fastening iron rods into stone may be accomplished by pouring hot lead or hot sulphur around the rods after they are placed in the holes drilled in the stone to receive them. Neat Portland cement is sometimes used for this purpose, and also a mixture of equal parts of sulphur and pitch.

35. Cements for Fireproofing.—A clay known as **fireclay** is extensively used to withstand high temperatures. The interior walls of brick-lined furnaces are often laid in fireclay mortar. In many instances, the bricks are omitted and the interior is plastered to the required thickness with the clay. This clay does not set in the sense of a chemical reaction taking place, but simply dries out. Fireclay does not possess a high tensile strength.

Another cement that will resist great extremes of heat is made from asbestos powder moistened with silicate of soda.

Ganister, made from ground quartz and fireclay, is also often used for fireproof purposes. **Parget**, made of lime, hair, and cow dung, was used formerly for house flue lining, though now not much employed.

LIME AND CEMENT MORTARS

36. Sand Used for Mortar.—The sand used in making mortar should be clean, sharp, and free from chemical salts. Any loam or clay in the sand will render it unfit for use with cement. Sand may be tested by rubbing it between the fingers. If the sand contains much loam, the fingers will become stained; but if they do not become soiled, the sand is probably clean. If squeezed in the hand, the particles of sand should fall apart when the fingers are opened.

Sea sand does not make a good sand for mortar, for two reasons. In the first place, the grains are round from being washed over one another by the action of the sea. This does not allow the cement to get as good a grip on the sand as if the grains were sharp and angular. Another objection to sea sand is that it contains salts that are *hydroscopic*, that is, attract moisture; this property would cause the mortar, even after becoming set, to be always damp and discolored. If sea sand must be used, it should always be washed free from its impurities and mineral salts before mixing in the mortar.

37. A discussion of the effect of the size of the grains of sand on the strength of mortar made by A. S. Cooper, led him to the conclusion that mortars become stronger as the grains of sand used become larger, up to sand that passes through a No. 12 sieve. In order to make good mortar, this size sand requires more cement than a smaller-grained sand. The custom, therefore, is to specify sand that will pass through a No. 20 sieve (wire No. 28, Stubb's gauge) and will be caught by a No. 30 sieve (wire No. 30, Stubb's gauge). By a No. 30 sieve is meant one with 30 meshes to the lineal inch, or 900 meshes to the square inch.

Crushed quartz, pulverized brick, cinders, furnace slag, and scoriæ are used in making mortar where sand is scarce. The general opinion is that these substances are as good, if not superior, to sand for mortar; the cost of pulverizing, however, adds to the expense, so that they are seldom employed when good sand can be obtained.

LIME MORTAR

38. Sand is added to lime or cement to increase the bulk and thus cheapen the material. It also has the additional advantage, when mixed with lime, of reducing the shrinkage that occurs while setting. Combined with cement, sand makes a mortar that sets slower than would the neat cement.

When sand and lime are mixed to make mortar, there should be enough lime in the mixture to completely cover each grain of sand. More lime than this causes the mortar to shrink excessively on drying. Less lime than the amount mentioned weakens the mortar. The correct quantity of lime to be added to sand to get the desired results is variously estimated by different authorities. Their opinions vary from one part of lime to two and one-half of sand to one part of lime to four parts of sand. The New York building laws require that one part of lime be mixed with three parts of sand. This mixture, as a rule, will be found very satisfactory.

39. For mixing lime mortar, a bed of sand is made in a mortar box, and the lime is distributed as evenly as possible over the bed, first measuring both lime and sand in order that the proportions specified may be obtained. The lime should then be slaked by pouring on water, after which it should be covered with a layer of sand or, preferably, a tarpaulin, to retain the vapor given off while the lime is slaking, or being converted into hydrate of lime by the action of the water. Additional sand is then used, if necessary, until the mortar contains the proper proportions.

Care should be taken to add just the proper amount of water to slake the lime completely to a paste. If too much water is added, the lime becomes too wet and will never attain its proper strength. If too little water is used at first, and more is added during the process of slaking, the lime will have a tendency to chill, and thereby injure its properties. Lime mortar made in large quantities and left standing in piles for use as may be needed is considered better practice than making it in small batches.

40. Using Lime Mortar in Freezing Weather.—Cold weather has two effects on lime mortar: it retards the setting and expands the mortar. The retarding of the setting is not detrimental, provided the weather remains cold for a long period. The expansion of the mortar due to freezing is not much of a drawback either, because the ice subsequently thaws and the water generally evaporates out of the mortar before setting commences. The danger is when the weather is cold and the sun shines on only one side of the wall and thus thaws the mortar on that side. There is danger then that the wall will settle unevenly. The best plan is to never lay mortar during freezing weather if it can possibly be avoided, because if a high wall were being built and the weather suddenly moderated, and thawed the mortar, a high wind would be liable to topple the wall over.

41. Advantage of Lime Mortar.—In connection with lime mortar, there is one great advantage that cement mortar can never have. That is, lime mortar has a certain amount of elasticity or give to it. This property is an important point in favor of using lime mortar, as it prevents many cracks in the structure that might otherwise occur.

CEMENT MORTAR

42. Proportion of Materials.—The same thing may be said in regard to the proportion of materials for cement mortar as was said about lime mortar; the cement should be in the correct proportion to just fill the voids between the grains of sand. If more cement is added, the cost of the mortar is increased; and if less cement is used, the strength of the mortar is decreased. A fact to be remembered, however, is that in either lime or cement mortar, the shrinkage caused in setting is not in the sand, but in the interstices between the grains of sand. Therefore, the more sand that a mortar has, the less it will shrink when setting.

43. Frost has the bad effect of retarding the setting of cement mortar. If the weather remains cold long enough for the water in the mortar to evaporate, there may not be enough moisture left for the chemical reaction of setting when the mortar gets warmer. On the other hand, if wet mortar begins to set and then freezes, the ice may break the set and ruin the work. A continuous spell of cold weather is not so hard on cement mortar as alternate freezing and thawing. Portland cement is less effected than natural cement by a freezing temperature.

In laying cement in freezing weather, one or more of the following precautions should be observed, according to the temperature and the importance of the work. Use a quick-setting cement. Make the mortar richer in cement than is customary. Heat the building, stone, cement, sand, or water, or all of these, as circumstances permit. Make the mortar as dry as possible. Add salt to the water to lower its freezing point. Cover up the finished work with clean straw, or a tarpaulin, but not with manure, as is sometimes done, because the acids in the manure are liable to injure the cement.

TABLE II

TENSILE STRENGTH OF PORTLAND CEMENT AND SAND

(*Directory of American Cement Industries*)

Cement Parts	Sand Parts	Pounds per Square Inch	Cement Parts	Sand Parts	Pounds per Square Inch
1	0	889	1	5	133
1	1	805	1	6	121
1	2	589	1	7	71
1	3	343	1	8	53
1	4	204	1	9	44

44. Cement mortar is made in various proportions, and the kind to use is simply a question of picking out the cheapest cement mixture that will answer the purposes best.

Table II gives the tensile strength of various cement mixtures, using good Portland cement, as found in a series of tests made at Holyoke dam, Massachusetts. The samples were allowed to set in water for 28 days before testing. The compressive strength is generally about ten times the tensile strength.

SPECIAL USES AND PREPARATIONS OF MORTAR

45. Cement mortar is not adhesive until it begins to set. Therefore, when used for pointing or for similar purposes, making it stay in place is sometimes difficult. A small quantity of lime added to the mortar will give it this property of adhesion and also cheapen the mortar. A substitution of from 1 to 20 per cent. of lime proportionately reduces the cost of the mortar, while the strength remains practically the same. Above this point, the strength decreases rapidly. A little lime added to cement mortar will also have a tendency to prevent freezing in cold weather and also makes it more waterproof.

In making cement mortar, first mix the sand and cement together dry, and then add sufficient water to reduce it to a thick paste.

By adding a small amount of cement to a lime mortar, the increase in strength is not in proportion to the increase in cost.

A lime-and-cement mortar sets faster than lime mortar and slower than cement mortar.

MORTAR COLORS AND STAINS

46. Artificial coloring, in mortar, has been known for hundreds of years, but its general use dates from a comparatively recent period. There are two totally different architectural objects aimed at in using colored mortar; one is to get the effect of a mass of color by concealing the joints, the other is to use a contrasting color to emphasize the joints.

Common bricks lose much of their rough effect when mortar of the same color as the brick is used, and the chipped or uneven edges do not show as plainly as they do when the bricks are laid in white mortar.

47. Most of the mortar colors consist of mineral pigments, sold either as a dry powder or in the form of a pulp or paste. Pulp colors seem to mix better with the mortar than dry colors, and are therefore preferable for the better class of work. Mortar colors, whether used in dry or pulp form, should never be mixed with lime until the lime has been slaked at least 24 hours. The color, however, should always be mixed very thoroughly with the lime putty before any sand is added; if the work is of a very fine quality, the colored mortar putty should be strained through a coarse sieve. When cement mortar is to be made, the color is mixed dry with the cement and sand.

The colored mortar looks different in the bed than when dry. The final color can be seen by taking a small quantity of the mortar from the bed and permitting it to dry thoroughly.

WATERPROOFING MORTAR

48. Ordinary lime mortar when set absorbs about 50 per cent. of its weight of water. Cement mortar absorbs about 12 per cent. of its weight. If a joint in a wall is saturated with water and then allowed to freeze, the moisture in the mortar joints, as it congeals, expands and has a tendency to crack off the pointing. In order to overcome this difficulty, it is sometimes deemed advisable to make the mortar waterproof. This is accomplished by adding 1 per cent. of powdered alum to the sand and 1 per cent. of soft soap to the water. These two substances, when combined, form an insoluble compound. With lime mortar, however, the waterproofing just mentioned retards the drying out of the interior portions of the work, on account of making those parts air-proof. Nevertheless, waterproofing makes the mortar somewhat stronger both in the initial and in the final set.

GROUTING

49. **Grout** is a thin mixture of lime or cement mortar and water. It is used, instead of stiff mortar, to pour in places where the latter would be difficult to apply. Grout should be used sparingly, as the excess of water seems to considerably lessen the strength of the cement.

CONCRETE CONSTRUCTION

MANUFACTURE AND APPLICATION

USE AND VALUE OF CONCRETE

1. The value of concrete as a substitute for stone and brick has been known for many centuries. Concrete found extensive employment in the construction of ancient Roman temples and palaces, being used for domes and arches, for the interiors of brick-faced walls, and for the foundation work.

Although, for many years past, engineering works of great magnitude have been constructed of concrete, it is only within a quite recent period that this valuable material has come into extensive use in the United States for building purposes, except as footings for foundation walls, for which it has long been used. While concrete will never take the place of stone and brick entirely, yet, both alone and in combination with iron and steel, it is of great value for various constructive purposes. Suitable materials for the manufacture of concrete can be found in almost every locality, which, with its comparative cheapness, makes it an important substitute for brick and stone in ordinary structures.

2. Aggregates.—The two materials used most extensively with cement and sand to form concrete are gravel and broken stone, and in order to make the resulting mass cheaper than pure cement mortar would be, either of these materials may be used in the mixture. A material thus mixed with a mortar is called an **aggregate**; while **concrete**

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is an aggregate and a mortar mixed. Some engineers consider that the word "aggregate" includes the sand also. This may be correct, but is not customary and will not be so used in this Section.

An aggregate must be free from clay or any other substance that might prevent the mortar from coming into direct contact with the gravel or broken stone. Although gravel is frequently used as an aggregate, it is smoother than broken stone; consequently, the mortar will not adhere so well. The pebbles forming gravel should not be too large, or they will not fit into small corners in the work. Broken stone makes a better aggregate than gravel, but it is often more expensive. The stone should be broken so that the largest pieces will pass through a ring 2 inches in diameter.

TABLE I

CRUSHING STRENGTH OF CONCRETE

Parts by Volume			Age of Concrete			
			7 Days	1 Month	3 Months	6 Months
Cement	Sand	Broken Stone	Crushing Strength in Pounds per Square Inch			
1	1	3	1,600	2,750	3,360	4,300
1	2	4	1,400	2,400	2,900	3,700
1	2½	5	1,300	2,225	2,670	3,400
1	3	6	1,200	2,050	2,440	3,100
1	3½	7	1,100	1,875	2,210	2,800
1	4	8	1,000	1,700	1,980	2,500
1	5	10	800	1,350	1,520	1,900
1	6	12	600	1,000	1,060	1,300

The small pieces of stone caused by the crushing should not be screened out, as is often done, because they help fill up the voids between the larger stones and thus decrease the amount of mortar required.

Other materials besides broken stone and gravel are sometimes used for aggregates. Either sea shells or furnace slags make good aggregates, and in the anthracite regions of Pennsylvania, "bony" coal is often found less expensive than broken stone and is used for cheap work.

3. **Compressive Strength of Concrete.**—On account of the developments in concrete construction, the compressive strength that may be developed in concrete is becoming an important consideration. Table I, which was compiled from tests made by George A. Kimball, at the Watertown Arsenal, gives the crushing strength of concrete made with several proportions of materials.

MIXING AND LAYING CONCRETE

MIXING CONCRETE

4. Concrete should be made by mixing a good quality of Portland or best natural cement with clean sharp sand and a proper amount of aggregate. The proportions vary for different classes of work, but a common ratio is one part of cement, three of sand, and six of stone or some similar material crushed to go through a 1½-inch ring. Any natural stone, gravel, broken brick, etc. may be used as an aggregate, but, whatever it is, it should be uniform in color and of an even grade. If a very close imitation of a natural stone is desired, the stone to be imitated should be crushed and used as an aggregate. In addition, color to correspond with that of the stone should be mixed with the cement. The finer the stone is crushed, the nearer will be the resemblance to real stone. For very good work, it is sufficient to break the stone to the size of buckshot or fine gravel.

5. **Hand Mixing.**—In preparing concrete by hand labor, the materials should be worked on a platform made of boards. This platform should have sides about 10 inches high, battened on the back, and should be laid on the ground near the work that is to be constructed. The platform is necessary, as it keeps the concrete off the ground and thus prevents loam or clay from mixing with the mass. As clay

will adhere to the stone and destroy close contact with the mortar, the effect will be to lessen the strength of the concrete.

The measured portions of sand and cement, while dry, should be thoroughly mixed by shoveling them together at least twice, so that there will not be different proportions of sand to cement in different parts of the concrete. Water is then poured on this mixture, which is shoveled over again until it has a pasty consistency. This mass is spread out in a layer about 6 inches thick, and the broken stone, which has been previously wetted, is distributed over it evenly. The concrete is finally mixed by turning the mixture over twice with a shovel, after which it is ready to be put in place.

6. **Continuous Mixers.**—When large quantities of concrete are needed, mixing machines are usually employed. A common type of machine, known as a **continuous mixer,** consists of a long screw about 18 inches in diameter, which is enclosed in a slightly inclined iron casing of a little greater diameter; the screw is operated by a crank that may be turned either by hand or by power. The cement, sand, and stone are introduced through hoppers at the upper end and the water is added through pipes at intervals along the length, and, as the screw revolves, the materials become thoroughly incorporated. The concrete is forced out at the lower end of the machine, falling into a bucket or other conveyer. After the concrete is made, the time between the mixing and the ramming should be as short as possible, in order to prevent the cement from setting before it is in place.

To hoist the prepared material, a traveling crane is sometimes used, the concrete being placed in buckets, which are transported to the proper place by the crane. Another plan is to have an elevator built at a central point on the site and carried to the full height of the intended building, runways being made to each floor as the work progresses.

7. Another style of continuous concrete mixer is **Gilbreth's portable gravity mixer.** This mixer, as shown in Fig. 1, consists of an inclined trough with projecting steel

pins, which are so arranged that the ingredients of the concrete will be deflected from one side to the other in descending, and thus become thoroughly incorporated. At the upper end of the trough, the pins are placed close together so that any pieces of stone that pass the first row will be certain not to clog in the other pins. In order that the concrete may be mixed dry before the water is added, the water connection is placed part way down the mixer. Water is

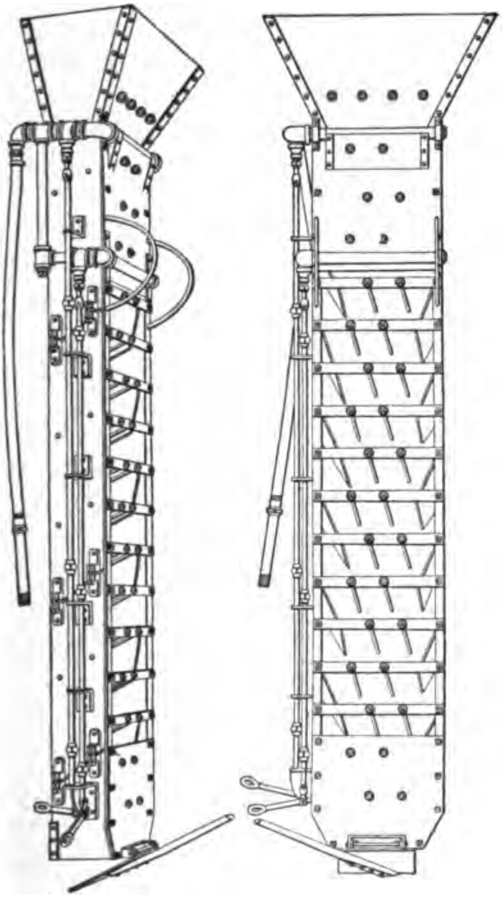

FIG. 1

supplied through a hose as shown in Fig. 2, which illustrates one of the many uses to which this mixer may be put.

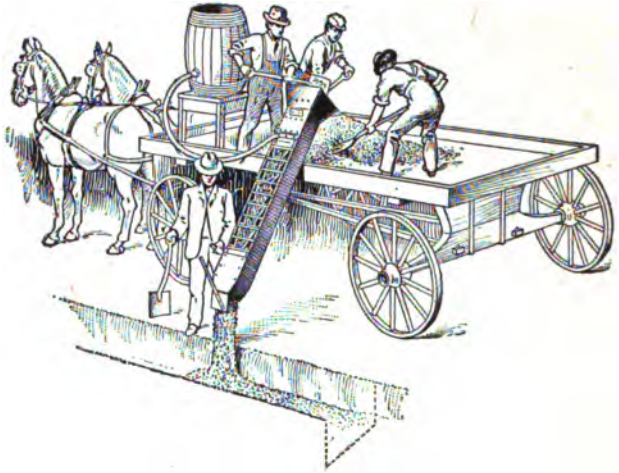

FIG. 2

8. Batch Concrete Mixers.—**A batch mixer** consists essentially of a large cylindrical or cubical box placed on trunnions. There are many types of these mixers, which are operated in various ways. In the oldest type, the ingredients are placed inside of the box, which is securely closed and revolved on the trunnions, thus mixing the contents thoroughly. In other mixers, the box, which is cylindrical, is open at both ends, and the materials are mixed by vanes attached to the inside of the cylindrical walls, the concrete being discharged as the machine revolves on its axis. With some types of mixers, this discharge is accomplished by tipping up the cylinder, and in others by inserting a chute in the end of the machine while the cylinder is in motion.

LAYING CONCRETE

9. When concrete has been dumped at the proper place, it is spread out and settled, by ramming, which should be continued until the concrete is thoroughly consolidated, and the cement flushes to the surface. The surface of each layer should be left rough for the succeeding layer, which is applied in the same way, until the required thickness is obtained. In order to make different layers of concrete bond together well, it is necessary to deposit a fresh layer before the previous one has become set, otherwise cracks are liable to develop in the finished work at the points where the layers join. Too much care cannot be exercised in these operations, as the value of concrete construction depends greatly on compactness and uniformity.

The making and placing of concrete should be very closely inspected, to insure the specified quality and proportions of cement and other materials, and also the proper manipulation. The cement, too, should be frequently tested during the progress of the work. On large and important work, an inspector should be constantly on hand, to see that the concrete is properly mixed and laid.

METHODS OF CONCRETE CONSTRUCTION

FORMS

10. When placing concrete, the usual method is to confine it in **forms,** or **molds,** on account of its tendency, when wet, to run and spread. Molds for concrete work are usually made of wood, and are removed after the concrete has set. While still wet, concrete exerts considerable pressure against the side of the molds.

11. Form Construction.—When building concrete walls, piers, arches, etc., the concrete is deposited in forms, or molds, made somewhat as follows: Posts of 4″ × 4″ or 4″ × 6″ timber are set up in pairs on opposite sides of the wall that is about to be formed, each pair being strongly braced to prevent springing. Against the inner sides of the uprights are laid planks 1 or 2 inches thick, the distance from face to face of the boards being just the thickness of the wall. The planks frequently have beveled ridges formed on the inner side, to produce the appearance of joints in the wall. This is shown in Fig. 3, in which *a* represents the posts; *b*, the boarding; and *c*, the molded or beveled strips, which make the apparent joints when ashlar is to be imitated. It is thus evident that concrete may be made to resemble any kind of stone masonry by varying the position and shape of the strips, or cleats.

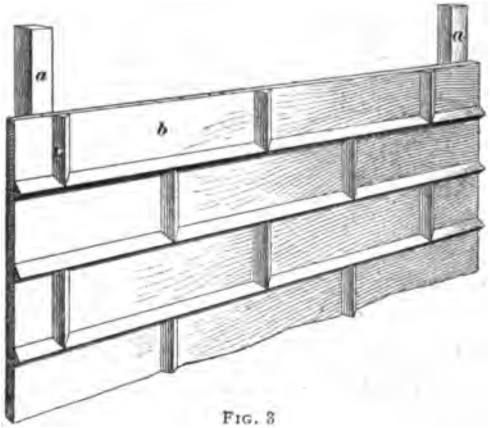

FIG. 3

It is sometimes recommended that the inside of the molds be washed with a solution of soap or crude oil before laying concrete between them so that it will not adhere to the wood.

After the lower portion of the concrete wall has set, the braces against the uprights are loosened enough to permit the withdrawal of the molding boards, which are put in place higher up. A movable cribbing is often used, and consists of slotted standards that may be raised when necessary without interfering with the work of laying the concrete.

12. The molds for rough concrete work do not necessarily require the same amount of care as the one just mentioned, and sometimes the boards are not even dressed.

An ingenious method that is used to support the molds for large work, and that is cheaper than the one shown in Fig. 3, is illustrated in Fig. 4. Here, *a*, *a* represents the mold proper, which is held in place by uprights *d*, *d* spaced about 2 feet on centers. The uprights are supported by 3″ × 8″ planks *b*, *b*, which are tied together with light steel rods *c*, *c*. After the concrete has set, it is only necessary to cut these rods and the mold falls apart. The rods are then clipped off close to the concrete, leaving the foundation ready for use.

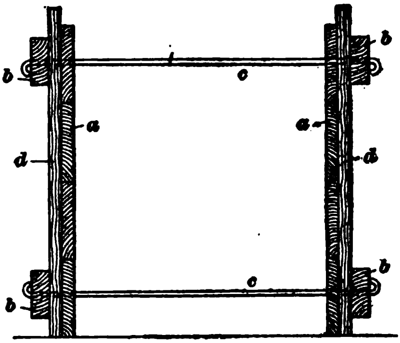

Fig. 4

13. Expansion and Contraction.—When it hardens in air, concrete contracts slightly, but often sufficient to produce cracks in the walls and floors. To obviate this, it is customary to employ some means to allow for expansion and contraction. The usual method is to make planes of least resistance in the work, which the cracks will follow and hence will not appear on the face of the wall.

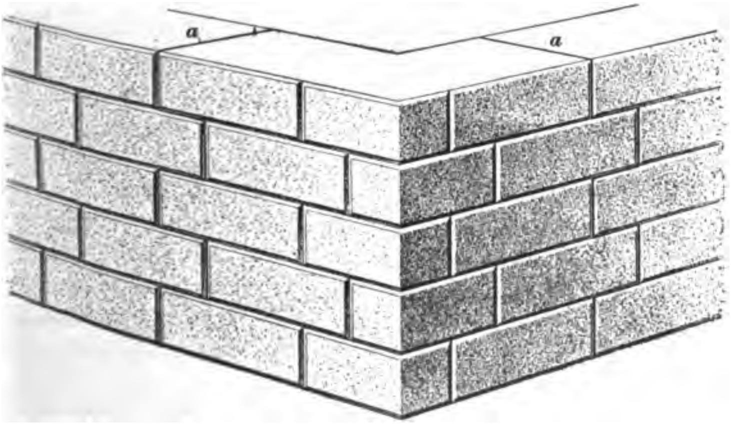

Fig. 5

A method of accomplishing this object is illustrated in Fig. 5. As shown at *a*, pieces of tar paper or other heavy paper are laid in the concrete in such a manner as to follow the course of the joints in the artificial stones. The paper should extend to within $\frac{1}{8}$ inch of the surface at each side of the wall so that if the concrete contracts it will crack in these places.

In placing band courses, trimmings, etc., great care must be taken to have them so arranged that shrinkage in the concrete will not injure them. All sills for windows should be slip sills, so that, if the wall settles, the ends of the sills will remain unbroken. For similar reasons, it is well to have the window lintels made in the form of a flat arch with a through joint at the center, and a recess for a key, which is put in later.

14. Surface Finish.—Up to within a few years, either plaster or mortar was used for the outside covering of most concrete buildings; this finish, however, does not prove satisfactory and increases the cost considerably. It is now not uncommon to cut the outside faces of concrete walls to closely resemble rough-dressed stonework. The effect of coursed stone or ashlar is produced by forming imitation joints in the face of the wall, as shown in Fig. 6, and afterwards either picking or tooling the surface. In imitating rough-dressed work, the crib, or mold, is taken from the wall before the concrete becomes absolutely hard, and the finishing may then be done very rapidly. When an imitation of finer tooled work is desired, the concrete should be allowed to harden for a longer period before being cut.

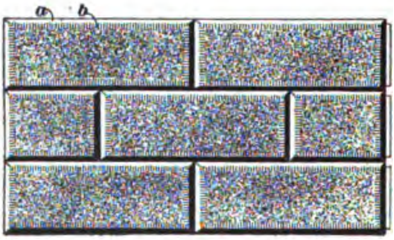

Fig. 6

Fig. 6 represents a method of finishing the face of concrete blocks: *a* shows the joint in the concrete; *b*, a margin, or draft, cut to imitate tooled work; and *c*, the picked face. If the strips that form the apparent joints are properly planed and beveled, the recessed joints will not require dressing.

CONCRETE CURBS

15. Concrete can be put to innumerable uses; foundations and pavements made of this material have been described in other Sections, the construction of walls has just been mentioned, and concrete fences and chimneys are made in practically the same way. Three additional uses of concrete are found in concrete street curbs, concrete building blocks, and reinforced-concrete structures. These are named in the reverse order of their importance, and will be discussed in the same sequence.

16. Combined Curb and Gutter.—In Fig. 7 is shown a method of laying a combined curb and gutter. The form consists of two 2-inch planks, each 10 feet long, with the edges and inside surfaces covered with sheet iron. One plank is 15 inches wide, and forms the side of the curb next to the sidewalk; the other is 9 inches wide and forms the side next to the street. Both planks are held rigidly in place by three cast-iron frames, to which they are bolted. The frames also carry the form, the curved under surface of which produces the trough of the gutter, and the outside (or street side) forms the curb. The mold, which is shown in cross-section, is 10 feet long and is accurately secured in line and at the proper grade by sighting along its top edges. It is then staked down by four long iron stakes, or spikes, that hook over the outside edges. This is done to prevent any movement during the process of ramming in the concrete filling. The mixed concrete is shoveled into the openings *A* and *B* and thoroughly rammed until the mold is full, and the top surfaces at these points are then troweled off flush with the top edges of the mold.

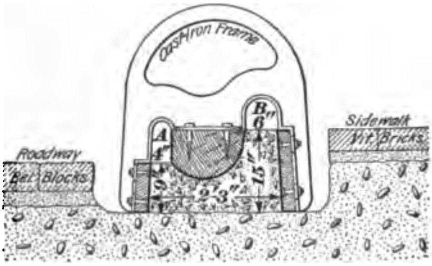

FIG. 7

As soon as the concrete filling has become sufficiently set, the stakes are drawn, the mold lifted off and moved along the line of the work, and placed in position to continue the process. When the mold is removed, the trough of this combined curb and gutter must be smoothed with a trowel in order to produce a more even surface in places where the concrete may not have been well rammed. This finishing may be done with neat cement mortar or with mortar mixed in the proportions of one part of cement to two parts of sand. The smoothing requires no special skill, and may be done rapidly.

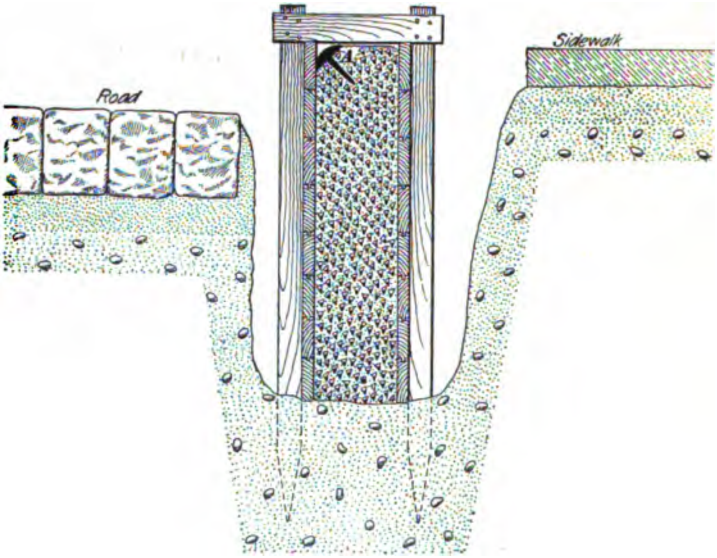

FIG. 8

Several lengths of mold may be used at one time, so that when the last is full the first will be ready to move along the line without loss of time. As soon as the concrete becomes sufficiently hard, the street and sidewalk pavement may be laid to join it.

17. Curbs.—A simple form of concrete curb, not including a gutter, is shown in Fig. 8. This curb is usually built in wooden molds as shown, which are removed after the concrete has set. As usual with all concrete curbs, this curb is divided into certain definite lengths by breaking its continuity with sheets of tar paper or some similar material. These joints are so placed as to insure that all cracks in the length of the curb due to shrinkage will be vertical and at definite points. A steel guard, as shown at *a*, is sometimes placed on the curb and serves to protect the concrete from the abrasion of wagon wheels.

CONCRETE BLOCKS

18. Although, as already stated, artificial stone has been employed for centuries, it is only within the last few years that concrete building blocks have come into extensive use. As a rule, these blocks are hollow in construction, which makes them both lighter and cheaper, and also has a tendency to keep walls built of them free from moisture.

A type of concrete block that is extensively used is shown in Fig. 9. The makers of these blocks claim that it is safe to plaster directly on the blocks on the inside of walls without using any furring and lathing, as the hollow construction will not allow moisture to penetrate to the inner surface. This is probably true in a short or gentle rain, but in a driving storm lasting for many hours, dampness is liable to soak through; therefore, particularly in exposed places, it will be found better to have hollow-block concrete walls furred and lathed on the inside.

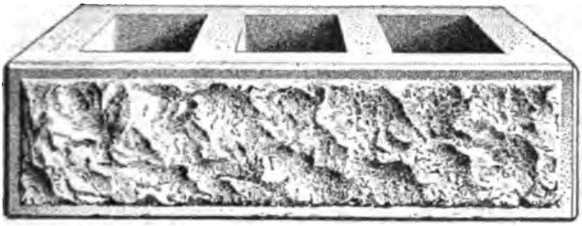

FIG. 9

19. Manufacture of Blocks.—In making concrete blocks, a machine having an iron mold is usually employed. Dry concrete, that is, concrete made with as little water as possible, is used, so that the block may be quickly removed from the mold and a new one cast. In this way, the molding machine will have a larger capacity than if wet concrete is used.

By changing the face of the mold, the blocks can be made to represent rock-faced work or any particular cut of stone that is desired. The color of the block can also be made to imitate various kinds of stone by using the proper kind of aggregate. Some makers, however, produce the desired shade by using artificial coloring.

Almost all building blocks are made of ordinary concrete, but many manufacturers use special ingredients or have a special process. It is common among some makers to cast the blocks under heavy pressure. This method has a tendency to make the blocks more dense, so that they will absorb less water. A very good imitation of Caen stone is made from a special cement called Caen stone cement.

20. The architect should exercise caution when selecting concrete building blocks, as many of them are cheaply made in order to compete with natural stone. For instance, some are sandy, absorb water freely, and present a dull regular appearance, which is often very far from the natural stone that is supposed to be represented. However, improvements are being made constantly, and there are today many reliable manufacturers that make first-class concrete blocks. Many of these use the *wet process;* that is, use sufficient water in the mixture to allow the concrete to attain its full strength on setting. The molds employed in this method are porous, and thus permit any superfluous water to escape. Stones made in this manner are very dense and do not absorb water readily; they can also be tooled the same as a natural stone.

The concrete blocks made by the Aberthaw Construction Company, of Boston, Massachusetts, are formed in various molds to suit the conditions of its use; sand molds, treated

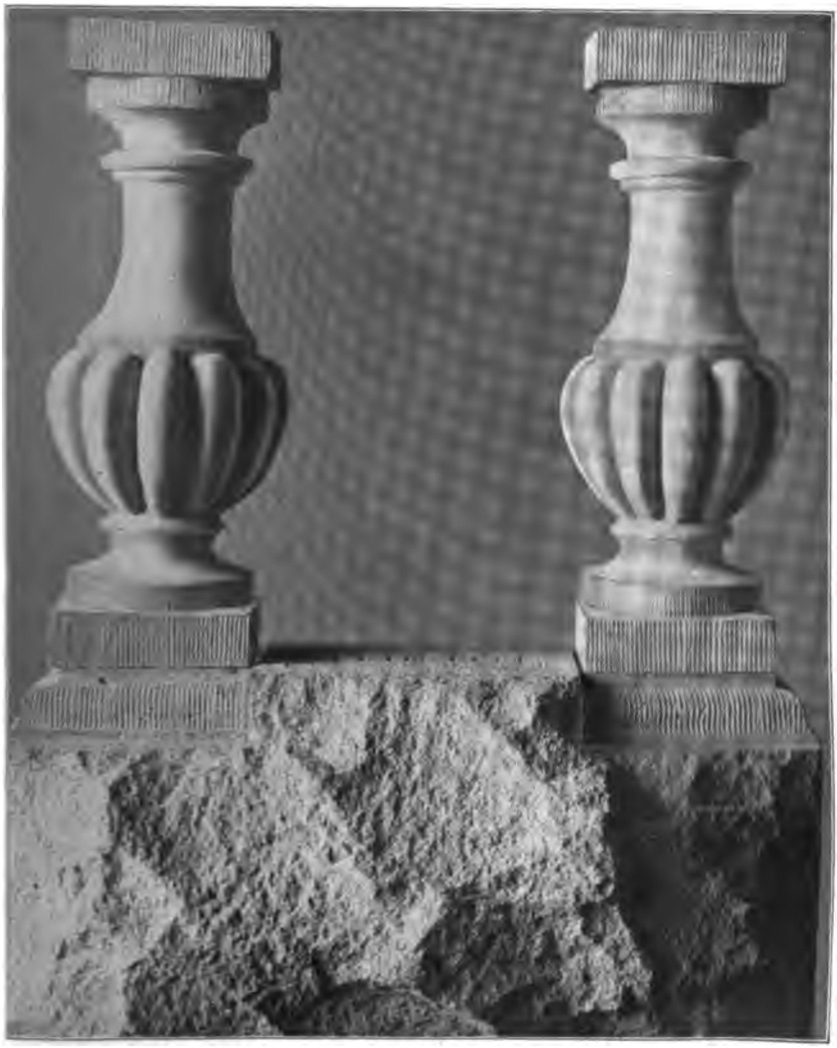

FIG. 10

sand molds, plaster of Paris, glue, or wood are employed, or sometimes the ordinary hollow-block molding machine. The color is varied by the use of aggregates of different colors and also by ordinary mortar colors. Sometimes, to get a very light effect, pure lime putty is added. Fig. 10 is a photographic reproduction of a specimen of artificial stone as made by the Aberthaw Company. Some of this material, particularly after it has been carved, is difficult to distinguish from natural stone.

REINFORCED CONCRETE

METHODS AND MATERIALS

21. Outside of foundation work, the most important use of concrete is in the construction known under the names of *ferroconcrete*, *concrete steel*, *armored concrete*, and *reinforced concrete*. The object of reinforcing concrete is to insert steel, either in the form of rods or of wire netting, so as to take up the strains of tension.

22. Economic Theory of Reinforced-Concrete Construction.—The tensile strength of 1, 2, and 4 concrete is about 250 pounds per square inch, and the compressive strength is about 2,500 pounds per square inch. The strength of steel is about 64,000 pounds per square inch in both tension and compression. At $7 per cubic yard, 1 cubic inch of concrete in place costs about $\frac{3}{200}$ cent, and at 3 cents a pound, 1 cubic inch of steel in place costs about $\frac{3}{4}$ cent. To resist 100,000 pounds in tension will require $100{,}000 \div 64{,}000 = 1.56$ square inches of steel, and $100{,}000 \div 250 = 400$ square inches of concrete. This will cost, if an inch long, for the steel $1.56 \times \frac{3}{4} = 1.17$ cents, and for the concrete $400 \times \frac{3}{200} = 6$ cents. Steel is therefore more than five times as cheap a material as concrete to use in tension.

On the other hand, to resist 100,000 pounds in compression will require 1.56 square inches of steel and $100{,}000 \div 2{,}500 = 40$ square inches of concrete. Therefore, for a length of 1 inch, the steel will cost 1.17 cents, and the concrete $40 \times \frac{3}{200} = \frac{3}{5}$ cent. The concrete is therefore almost twice as cheap a material as steel to use for resisting compression.

23. **Cracks in Concrete.**—The adhesion between smooth steel and concrete is about 300 pounds per square inch. When concrete and steel are combined, the concrete may stretch to such an extent that it will be ruptured, causing small, almost invisible, cracks before the steel is stretched beyond its elastic limit. However, when the load is removed the concrete, which during this time has been held in place by the steel, will return to its original position. The concrete is then as good as ever to resist compression, although, of course, it will not stand tensile stress. Therefore, these fine cracks do not injure the structure, because if properly designed the concrete is not supposed to resist any tensile stress.

24. **Corrosion in Steel.**—Protecting the steel in the concrete against corrosion is a problem that has been much discussed. It seems, however, that ordinary cement with its alkaline reaction is a good preservative against rusting, provided there are no cracks through which water and air can penetrate. There is at the present time considerable difference of opinion on this point, nevertheless many of the older reinforced-concrete structures have been opened and the steel found to be as bright and clean as when it was put in. However, in the anchorages of the Niagara railroad bridge the strands of the main cables embedded in concrete were found to be eaten through in some places. Many engineers claim that this corrosion was not due to the cement, but was caused by the limestone aggregate.

Therefore, according to the best information, concrete may correctly be considered a good preservative of steel against corrosion, but care should be taken not to use limestone as an aggregate, for it is considered injurious to the steel. Cinders are also considered injurious in some instances, as when used in large proportions as an aggregate.

25. In the proportion of 1, 2, and 5, concrete made from cinders is absolutely fireproof and almost entirely protects the steel from corrosion. If used with a larger proportion of cinders than this, however, the concrete should be laid with caution, for if the cinders come in contact with the steel, corrosion is liable to occur.

26. Concrete as Fireproof Material.—To show how completely concrete protects steel from fire, it is merely necessary to say that properly made reinforced concrete is fireproof. If the steel is embedded at least 1½ inches in the concrete, it is safe from any ordinary conflagration unless the protecting concrete is broken off. Time and time again, both in experimental tests and in disastrous fires, reinforced concrete has been tested and found fireproof, and often superior to the structural-steel fireproof construction now in common use.

27. Reinforced concrete was given a severe test in the Baltimore fire of 1904. A survey of the United States Fidelity and Guaranty Building of that city, which was composed of floor systems carried by reinforced-concrete columns and girders, showed that though the cast-iron front and the brick party wall of the building had been destroyed, the concrete floor systems and their supporting columns remained in place. In Fig. 11 is shown the condition of the building several weeks after the fire, some of the party wall having been removed. When in this condition, the floors of the building were tested without failure, the load being 400 pounds per square foot. Even the overhanging portion *a* sustained a load of 200 pounds per square foot without damage. The reinforced concrete of which the structural members of this building were constructed was composed of crushed granite, sand, and American Portland cement. Most of the plaster in the building had fallen from the concrete, thus making it evident that the plaster afforded no adequate protection.

28. Rigidity of Reinforced-Concrete Construction.—Joints similar to those used in the column and girder connections in structural-steel work do not occur in reinforced-concrete construction; consequently, reinforced-concrete structures are practically monolithic and extremely rigid. This construction is particularly desirable for buildings that contain looms, presses, rotary mills, or any machinery likely to run in unison and produce considerable vibration, which is sometimes very disastrous in buildings of ordinary construction.

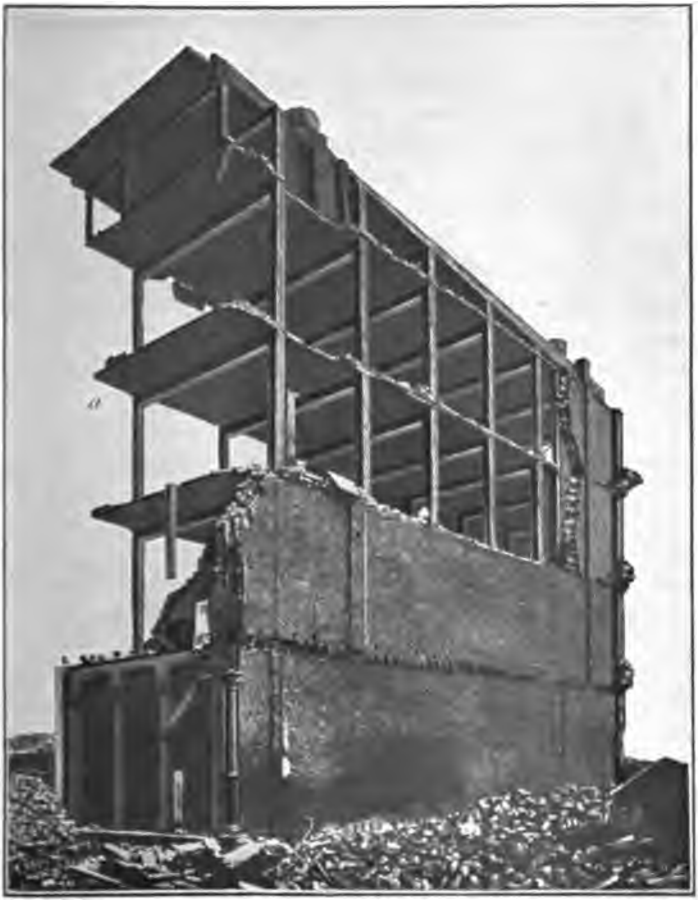

FIG. 11

USES OF REINFORCED CONCRETE

29. Reinforced concrete is mentioned in previous Sections in connection with its use for piles and footings, and in *Fireproofing of Buildings* its use for floors, partitions, and other parts to be made fireproof will be taken up. In this Section, the purpose is to describe the uses of reinforced concrete in building construction, exclusive of foundations and fireproofing, for columns, beams, outside walls, etc. However, it must not be inferred that these are the only uses to which concrete can be put. The architect only begins the list of its uses. Reinforced concrete is employed for bridges, cisterns, culverts, dams, harbor work, sewer pipe, railroad ties, reservoirs, standpipes, and innumerable other purposes.

REINFORCED-CONCRETE WALLS

30. Classification.—Reinforced-concrete walls may be divided into two classes; namely, the *solid wall* and the *hollow wall.* The solid reinforced-concrete wall does not require to be very thick, and for this reason is liable to become wet through during rainy weather. Walls of this kind are therefore not well adapted for house construction, but they are commonly used for mill buildings.

31. Solid Walls.—A solid reinforced-concrete wall, such as would be built for a mill or factory, is shown in Fig. 12.

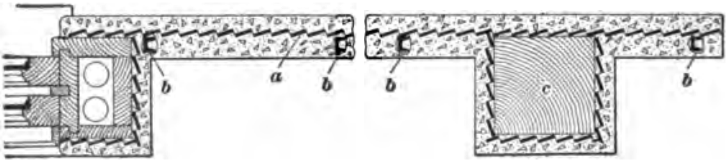

FIG. 12

The expanded metal, shown diagrammatically at *a*, is wired to studs made of small channel irons, as shown at *b*, *b*. A steel I beam may be substituted for the wooden post *c*, if it is desired to make an all-fireproof structure.

32. Hollow Walls.—A double wall made of expanded metal is illustrated in section in Fig. 13. Wires are used to tie the expanded metal to the studs, which are made of steel angles that are placed opposite each other in the two walls, being fastened together by metal straps riveted to each angle.

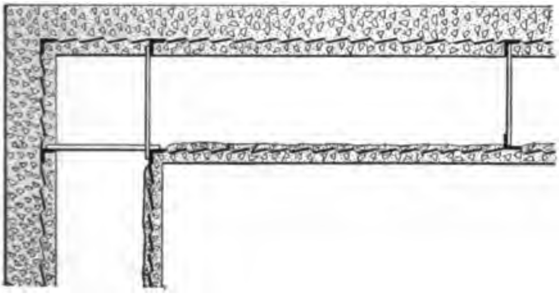

FIG. 13

In cheaper construction, wooden studs are run up between the walls, and the expanded metal of both walls is tacked on the opposite sides of each stud, as shown in Fig. 14.

33. In a construction such as shown in either Fig. 13 or Fig. 14, the outside wall of concrete must be finished before the expanded metal used for the inside wall is put in place. This is done so that the inner surface of the outside wall may be properly finished. The walls are usually composed of cement-and-lime mortar, cement mortar, or cement concrete with a finely broken aggregate. When using expanded metal, wooden forms to confine the concrete or mortar are not necessary, as it can be put on the expanded metal the same as any other plaster. The subject of concrete walls reinforced with expanded metal or other forms of netting or bars will be further discussed in *Fireproofing of Buildings*.

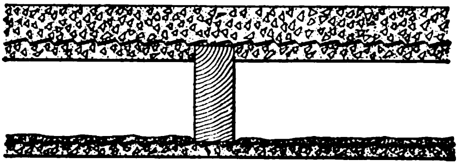

FIG. 14

34. In Fig. 15 (*a*) is shown a corner of a concrete house reinforced with plain steel rods and built with hollow walls. Any form of patent rod described in *Footings and Foundations*, however, can be substituted for the smooth rods shown in the illustration. At *a* is shown a 6-inch outer concrete wall; at *b*, a 2-inch inner wall; and at *c*, *c* are shown vertical withes that tie the two walls together. The ¾-inch rods in the outer wall are shown at *e*, and the ½-inch rods in the inner wall at *f*, these rods being placed about 3 feet apart. At *d* are shown the tie-rods in the floor construction. In the withes *c* are placed ¼-inch rods, which are set horizontally and spaced vertically about 8 inches apart. These rods are shown in detail in Fig. 15 (*b*).

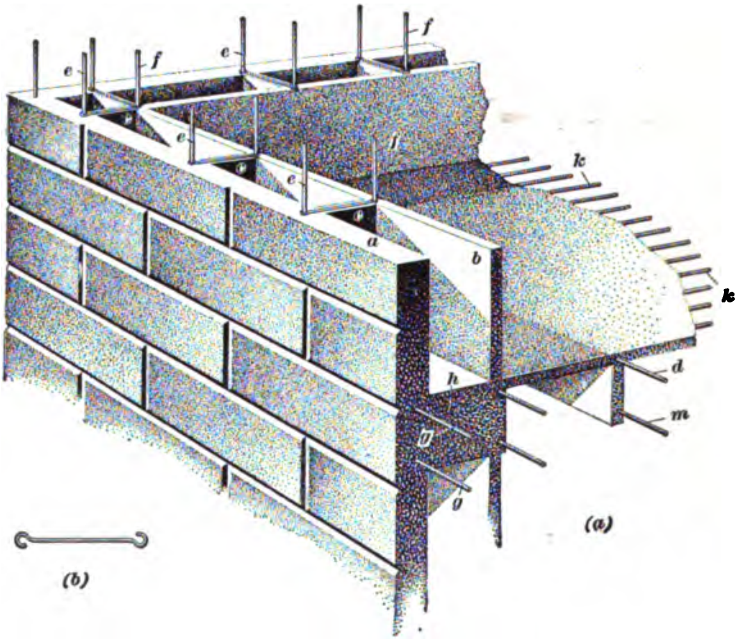

Fig. 15

At each floor level, ¾-inch bars are embedded in the walls, as shown at *g*, and at all meeting or crossing points, the rods are securely tied to one another with wire. The space between the walls, which is about 12 inches, is stopped at each floor, as shown at *h*, except in those portions used for ventilation or for smoke flues, where the space is continuous. The floors are 2 inches thick, and are reinforced with $\frac{3}{8}$-inch rods *k*, *k* placed on 6-inch centers. The floor is supported by joists, which are reinforced by $\frac{1}{2}$-inch rods, as shown at *m*. This form of construction is superior to hollow brick walls, as practically no moisture can pass through the concrete withes.

35. Skeleton Construction.—A reinforced-concrete mill building of the rigid-frame type in course of construction is shown in Fig. 16. Sometimes, the outside walls of buildings of this kind are made of brick without concrete piers in them, in which event only the floor and middle columns are made of reinforced concrete. In the illustration, however, the outside piers are of concrete and are

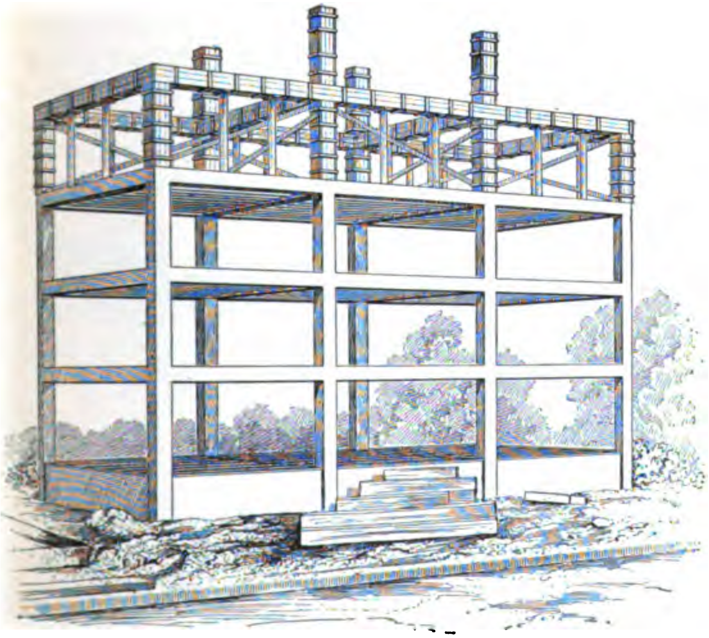

FIG. 16

built monolithic with the girders and floors. When curtain walls are used, only the columns, girders, beams, and floors need be built first, and these principal parts are in practically one piece. The outside piers have copper ties cast in them, to which the brick veneer that is to be put on afterwards can be secured. The illustration shows the wooden forms being put in place in the fourth floor, while the first three floors are all ready for the enclosure walls. The forms that hold the concrete should be allowed to remain for at least a week after the concrete has been put in place.

REINFORCED-CONCRETE BEAMS AND GIRDERS

36. The construction of columns and girders used in a building like the one shown in Fig. 16, is worthy of study. Reinforcing is accomplished by simply placing rods that run the full length of the girder near the under side. These rods may be ordinary round rods or they may be some patent rod, as the Thatcher or the Ransome bar. The usual method of constructing a reinforced-concrete girder, however, is shown in Fig. 17, and the reinforcement consists in placing round steel bars so that one is vertically over the other.

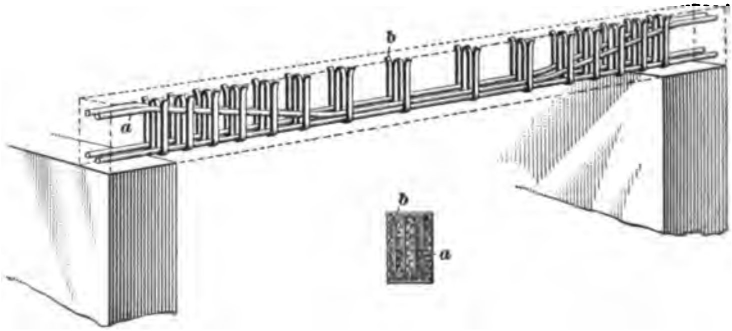

FIG. 17

For narrow beams, only one set of rods is employed, but in the illustration a beam is shown having two sets of rods, which number is frequently used. The upper rods are bent to slope up to the top part of the beam at its supports, and the reasons for this arrangement is as follows: The tensile stress in the under side is less at the ends than near the middle of the span of the beams; therefore, less steel is required at the ends to withstand this stress. Also, when concrete beams are reinforced with a high percentage of steel, and this steel is placed at the bottom only, the beams will fail as shown in Fig. 18. The cracks *a*, *a* are caused by a combined shearing and tensile strain in the concrete, and to avoid this, the rods *a*, Fig. 17, as already mentioned, are bent up.

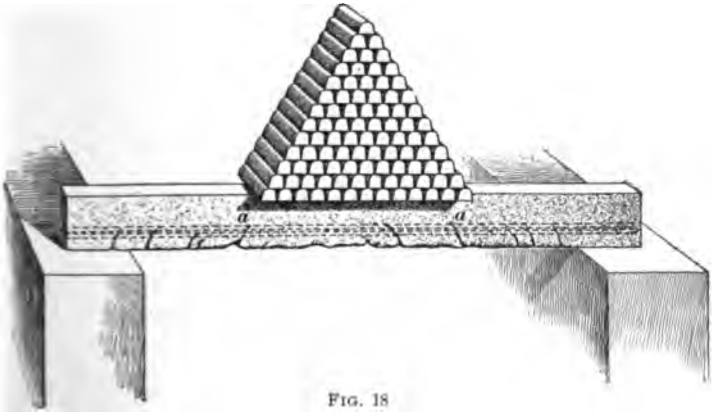

FIG. 18

37. It will be noticed in Fig. 18 that there is a tendency when the beam is overloaded, or in case of fire, for the concrete to break away from the bottom portion at the ends as far up as the rods. In such a case, the rods become entirely stripped of concrete and do not act in unison, which of course reduces the strength of the beam. To insure that the rods will always be secured to the beam, **U**-shaped stirrups *b*, Fig. 17, are inserted. These stirrups also resist the tendency of the concrete to crack, and thus strengthen the rod *a*. The stirrups are placed closer together at the ends where the strains are greatest.

38. When a girder is supported by three or more supports, it is customary to extend the bent rods across the points of support in the top of the beam at each inside support, so as to take up the tensile stresses that occur there. This construction is illustrated in Fig. 19, where *a* is the middle support, or column, and *c*, *c* are the extensions of the curved rods past the line of the column.

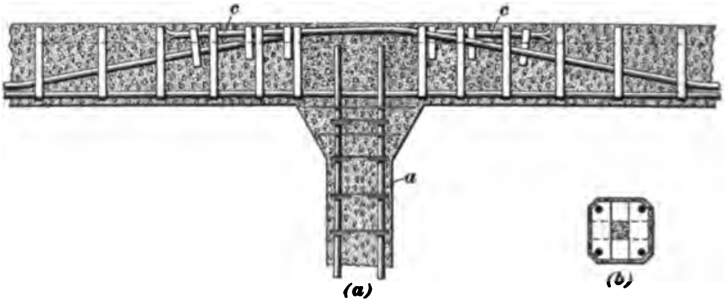

FIG. 19

THE KAHN SYSTEM OF REINFORCEMENT

39. Besides the method for the reinforcement of concrete beams just described, there are many patent steel reinforcements, and a few of them will be mentioned here.

The **Kahn system** of reinforced-concrete construction is illustrated in Fig. 20, which shows the shape of the reinforcing metal for beams and columns. The Kahn standard bar is shown in section in Fig. 21, and consists of a central rib *c* with a web *d* on each side, which may be so bent as to take the place of the inclined bars and stirrups employed in the usual method of reinforcement. This is accomplished by shearing the webs *d* along the rib *c* for a certain distance and bending them into the positions indicated at *a*, Fig. 20. It is evident that a bar bent up as described cannot slip through the

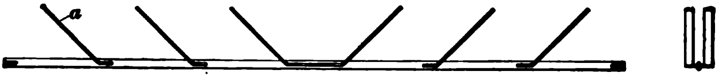

FIG. 20

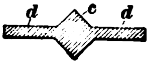

FIG. 21

concrete, and, therefore, it must resist all the tension produced in the beam, provided the concrete is so proportioned that it will not fail. When a load is applied on top of the beam, the concrete throughout the whole length of the beam tends to arch itself, the steel bar in the bottom acting as a tie.

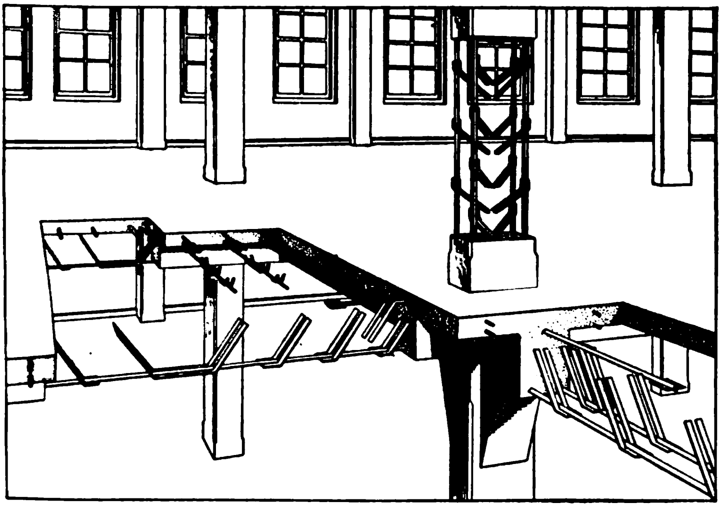

FIG. 22

The general manner of using these bars is shown in Fig. 22. It will be noticed that not only the girders but also the columns are reinforced with this bar.

THE UNIT CONCRETE STEEL REINFORCEMENT

40. Another patented type of reinforced-concrete construction is illustrated in Fig. 23. This construction is known as the **unit system**, and takes its name from the fact that all the metal necessary for the actual reinforcement of the concrete girder is fastened in one piece. The steel reinforcement of the unit-girder frame section consists of four round bars connected with a thin web, as shown in Fig. 23 (*b*). For a considerable distance from each end, the web is sheared through the section at *a*, *a*, and the round bars with the

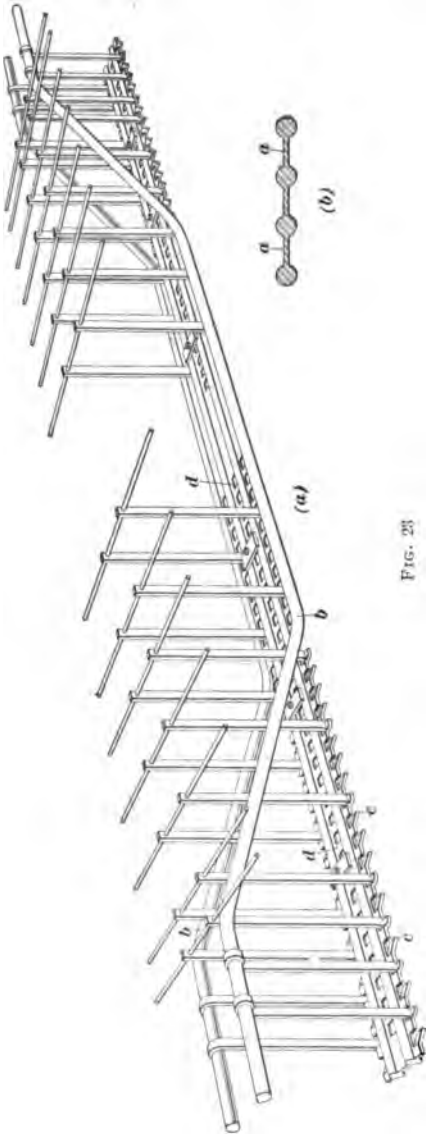

Fig. 23

attached portion of web are bent up like a trussed girder, as shown at *b*, *b*, Fig. 23 (*a*). The web remaining on the two central bars of the bulb-formed rolled section is punched and bent downwards, as shown at *c*, *c*, while the web between the two inside bars of the rolled section is punched out at intervals, forming slotted holes, as shown at *d*, *d*. It will be observed that the trussed frame is supplied with stirrups consisting of $\frac{1}{8}'' \times 1''$ bars that are punched at the upper end so as to allow the steel reinforcing members of the concrete floor between the girders to pass through them. These bars are **U**-shaped, as shown, and are bent at the bottom to fit the shape of the rolled section, where they are securely held in place by bending back the prongs *c*, *c*. The stirrups toward the end of the bar are arranged somewhat differently at the top, being bent around the upper bar, as shown in the illustration, thus tying the top and the bottom together.

REINFORCED-CONCRETE COLUMNS

41. Common Methods.—There are two distinct types of concrete-steel columns. Fig. 24 shows the common form, which consists of four rods set out toward each corner of the column. These rods are held together at intervals by plates, as shown. A stronger column is shown in Fig. 25. Steel wire is used in this case, and is considered preferable to the metal plates shown in Fig. 24. These ties, however, whether wire or plates are used, must be so spaced that the rod reinforcement cannot bulge between two tie-points. It is generally found sufficient to place the ties at a vertical distance above one another equal to the least diameter of the section of the column.

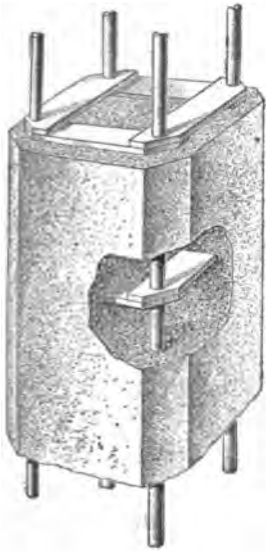

FIG. 24

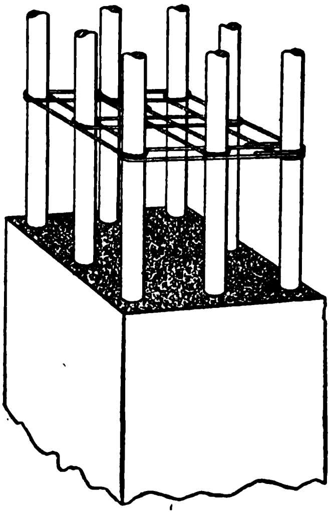

FIG. 25

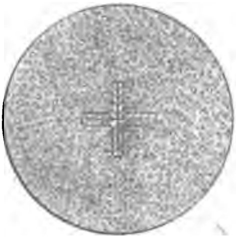

FIG. 26

42. In some buildings, columns of reinforced concrete have been constructed by placing four structural steel angles back to back, as shown in Fig. 26, and then putting concrete around them. This practice, however, is hardly as good as those shown in Figs. 24 and 25, because the center of a column is probably not the best place to have the steel reinforcement.

43. Hooped Column.—The other style of reinforced column referred to is known as the **Considerè, or hooped, column.** It has an advantage over the ordinary reinforced column in that it can be made much smaller in diameter for the same load. This column is made by embedding in the concrete a steel spiral slightly smaller in diameter than the outside of the column, as illustrated in Fig. 27. Columns constructed in this manner usually fail by bending and not by shear, as do the ones shown in Figs. 24, 25, and 26. The hooped column finds extensive employment at present in France, and will doubtless, in the future, come into general use in America.

44. Besides being hooped, columns are often reinforced in addition by placing vertical rods inside of the spiral. Sometimes, instead of a spiral, the column is hooped by one or more sheets of expanded metal, as shown in Fig. 28. The great objection to the hooped-concrete columns is that the concrete, if subjected to a severe fire, is liable to crack off as far in as the hooping.

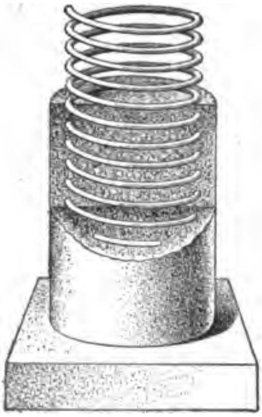

FIG. 27

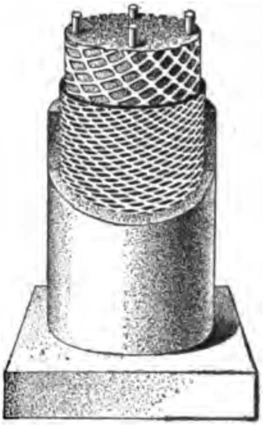

FIG. 28

STONE MASONRY

STONE CONSTRUCTION

GENERAL CONSIDERATIONS

1. The stonework entering into the construction of buildings may be divided into three classes: *rubble*, *ashlar*, and *trimmings*. Before describing these, however, a few general observations, applying to all classes of stone masonry, are necessary.

Whatever may be the quality of mortar used, the wall should contain as much stone and as little mortar as possible, as the former is the stronger material. In rough walling, if the stones are pressed together until the more prominent angles on their faces come almost into contact, the interstices being filled with mortar, there results better work than if a thick, yielding mass of mortar is allowed to remain in the joints. Absolute contact is not advisable in stonework, any more than in brickwork, as the mortar in drying shrinks and may leave the stones bearing only on the projecting angles.

The joints in stonework vary in thickness from $\frac{3}{16}$ to $\frac{1}{2}$ inch; a $\frac{1}{4}$-inch joint is probably the best for ordinary work, while a $\frac{1}{2}$-inch joint should be used for rock-faced work only.

2. Stone being of a brittle nature, the longer pieces in a wall must be properly supported and well bedded in order to prevent them from breaking. It is also best to avoid extremely long lengths, although the length of a stone should be greater than its height, especially in ashlar work, on

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account of the vertical bond. There is a certain medium that should be observed; and while a compact mass, broken as little as possible, is most desirable in stone as well as in brick walls, the mason will often find it better to break a very long stone into two or more shorter ones, even though by so doing additional joints are made. However, in laying very long stones, as steps or copings, it is customary to bed them only at the ends, so that when the mortar joint shrinks there will be no danger of the stones being broken by bearing on some obstruction at their middle.

The best stones should be used for piers, jambs, sills, lintels, cornices, band courses, etc. in the order mentioned; and all stones that are longer on the face than their heights should be so quarried that they can be laid on their natural beds, except, of course, piers and long jambs, which necessarily have the bed of the rock vertical.

3. Defective Methods.—A stone with a hollow cut in it, as shown at *a*, Fig. 1, should never be used in a wall, for when the mortar shrinks, the stone will bear only at the edges and is liable to spall, with the result shown in the illustration. If not closely watched, careless stone masons are tempted to cut stones in this manner, as it is much easier than cutting them to a true bed. Another improper method often carried out by masons is to cut the stone as shown in Fig. 2 and underpin the back with spalls. This practice is also liable to lead to disaster, as the stone may split as shown at *a*.

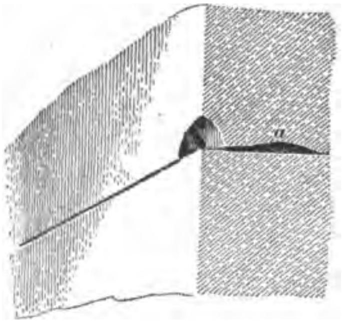


FIG. 1

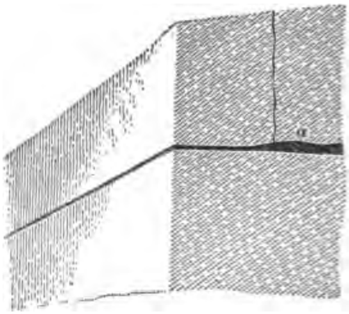


FIG. 2

Rusticated joints are ordinarily used in the basement and first story of tall buildings to lessen the liability of spalling in the lower courses of stone.

4. **Cement and Mortar.**—For damp places, stonework should be laid either with cement or with cement-and-lime mortar, while for dry situations, lime mortar may be used. Cement is always preferable, however, for general use.

In work that is to be pointed, no mortar should be placed within an inch of the front edges of the stone, as this saves raking out the joints preparatory to pointing. Sometimes, slips of wood the exact thickness of the joint are set on the edges of the lower course; in setting the stone, the superfluous mortar is pressed out and the stone rests on the wooden slips, which are removed when the mortar is hard. No mortar for pointing is better than pure well-slaked lime mixed with two parts of washed hard sand and the required amount of coloring matter. The mixture should be worked until the mass assumes the consistency of glaziers' putty. The tints of the mortar used for pointing should be of a shade that will give relief to the blocks and also softly blend with the general shade of the stone; but care should be taken not to make the joint lines too striking as, by so doing, it imparts to the work a harsh and repellent appearance.

5. Portland and Rosendale cements discolor most limestones and marbles, and some sandstones. By exercising care, the mortar may be kept from the face of the stone, and the joints may be pointed afterwards with mortar that will not stain. A cement made of plaster of Paris, lime, and marble dust, called *Lafarge cement*, is sometimes used for setting marble and limestone; it is claimed that this will not cause discoloration.

RUBBLE WALLS

6. **Rubblework** consists of stonework in which the stones have not four sides dressed to form right angles. It is used for rough masonry, as in foundations, backing, etc., and frequently consists of common field stone, roughly dressed; but whenever possible, quarried rubble should be

used, as better bedding can thereby be secured. Conglomerate and slate stones abound in many localities, and are cheap and durable, but do not cut easily. They are often used with good effect, however, in walls with cut-stone or brick trimmings; or, when good lengths can be had, for rock-faced sills, lintels, and trimmings.

7. Fig. 3 represents a good rubble wall, the stones being bonded about every 4 or 5 feet, as shown at *a*; the largest and best stones should be placed at the bottom and at the angles, as indicated at *b*, laid up in alternate courses of headers and stretchers. Such work is generally laid with beds and joints dressed but very little, the rough angles only being knocked off; the stones are set irregularly in the wall and the interstices are filled with spalls and mortar. If better work is desired, the joints and beds of the stonework should be hammer-dressed. The walls are frequently pointed with colored mortar, showing raised joints.

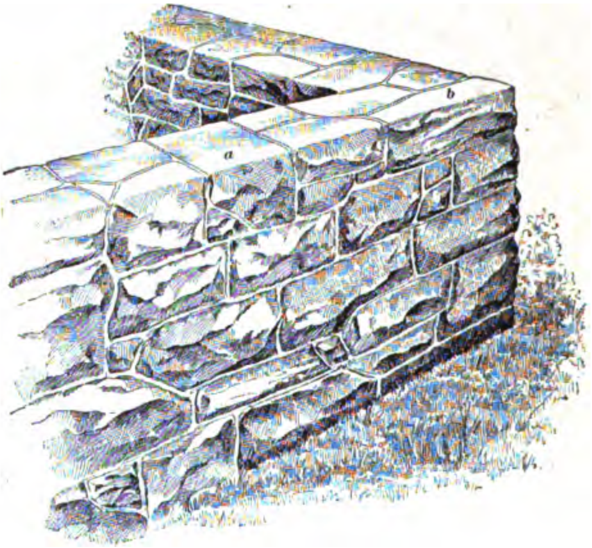


FIG. 3

8. Fig. 4 shows a form of rubble masonry much used for country and suburban work. The *quoins*, or corner stones, *a* are hammer-dressed on top and bottom, and may be either cut stone or rock face; the latter harmonizes well when stones similarly dressed are in the body of the wall.

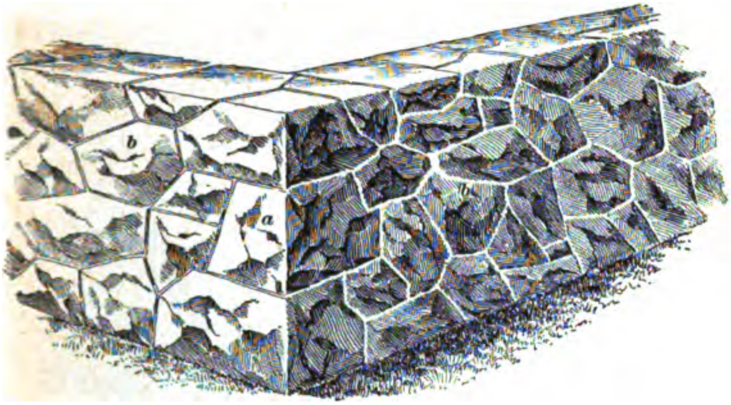


FIG. 4

All joints should be hammer-dressed, as shown at *b*, and no spalls should show on the face, while the mortar joints should not exceed $\frac{1}{2}$ to $\frac{3}{4}$ inch in thickness. This makes an effective wall, especially for country churches, lodges, and other small buildings; but the work is expensive, owing to the labor required in dressing the joints.

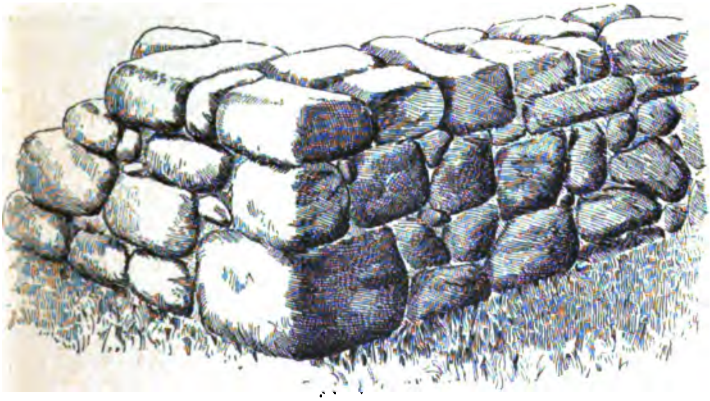


FIG. 5

9. Field-Stone Walls.—In Fig. 5 is shown a **field-stone wall.** Walls of this kind are built of small, uncut boulders, and are frequently employed for fences and rustic-house work. These walls should be made quite thick on account of the round and unstable shape of the stones used in their construction.

10. Walls With Brick Quoins.—Fig. 6 shows a rubble wall with **brick quoins,** or corners, at *a*. In this case, all the top and bottom joints of the rubblework have *level beds*, as at *b*. This makes a very effective wall, and can be built quite cheaply when the stone used splits readily, or can be laid on its natural bed, thus requiring but little dressing.

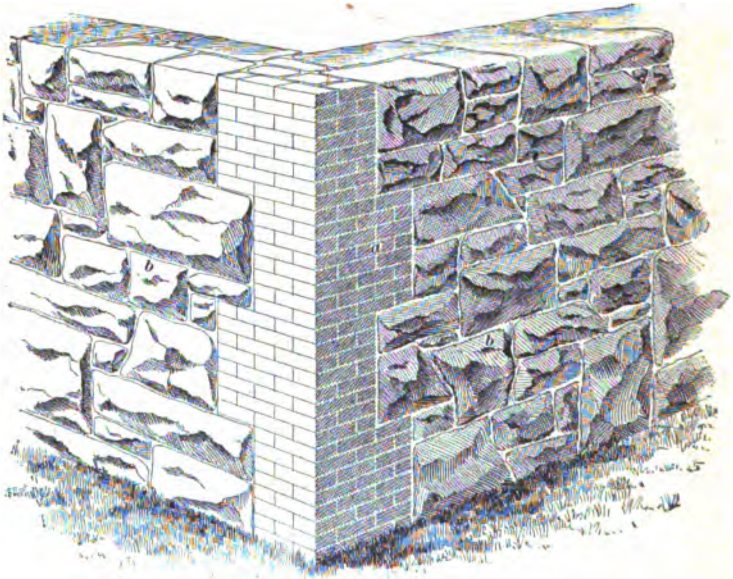


FIG. 6

11. Coursed Rubble.—In walls of coursed rubble, some effort is made to produce a coursed effect, using stone of random sizes; little or no attention, however, is paid to uniformity of height in the different courses. For such walls, the stones are generally roughly dressed by the mason before he begins work. Care should be taken to get as nearly parallel beds as possible, and to bring the face of each stone to a fairly even surface at approximately right angles to the beds. The quoins, or corner stones, in coursed rubble are usually dressed and laid with more care than the remainder of the work, and also serve as gauge courses. Coursed rubble, when well built, makes a very solid wall and is extensively used.

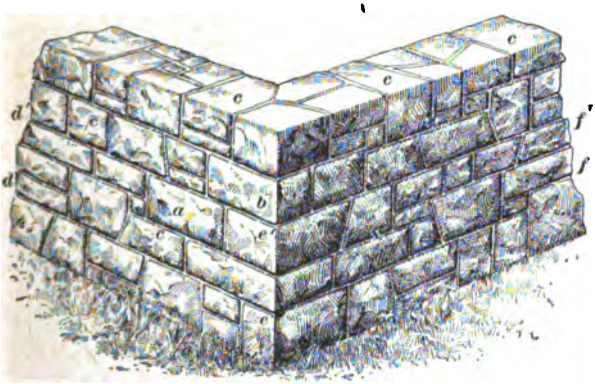


FIG. 7

Fig. 7 represents a coursed rubble wall, *a* showing the rubblework; *b*, the quoins; *c*, *c*, the bond stones running through the walls; and *d e f* and *d' e' f'*, two of the course joints.

ASHLAR

12. **Classification of Ashlar.**—Stonework that is cut on four sides so that the opposite sides will be at right angles to each other, is known as **ashlar**, no matter whether the face is dressed or not. In the following description it should be understood that the style of ashlar designated has nothing to do with the finish on the face of the stone, but simply the manner in which it is laid, although, certain kinds of ashlar are generally made with the styles of dressing shown in the illustrations.

Ashlar is usually laid either in regular courses with continuous horizontal joints, as shown in Figs. 8, 9, and 10, or in broken courses, without regard to continuity of the joints, as shown in Figs. 12 and 13. All ashlar should have straight and horizontal bed joints, and the vertical joints should be kept plumb. Failure to do this mars the effect of the work very materially.

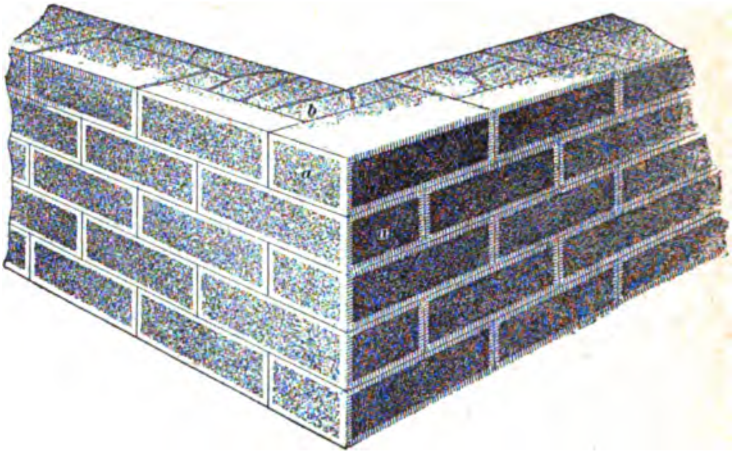


Fig. 8

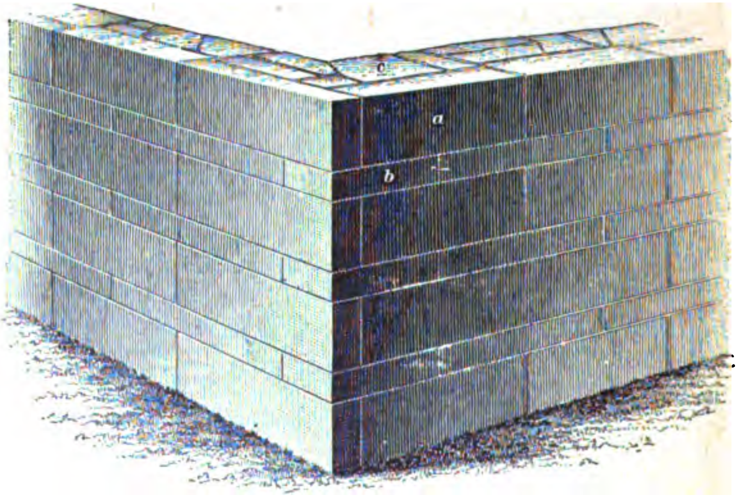


Fig. 9

13. Coursed Ashlar.—A class of stonework in which the pieces are uniform in size and the bed joints are continuous is known as **coursed ashlar.** When such stones can be obtained readily, this is not a very expensive kind of work. A coursed-ashlar wall is shown in Fig. 8, where *a, a* indicates the 12″ × 36″ ashlar, and *b* the backing, which consists of 12-inch rubble.

14. A good effect is produced by making the courses of two heights, but cut in regular sizes, and having the vertical joints in alternate courses directly over one another.

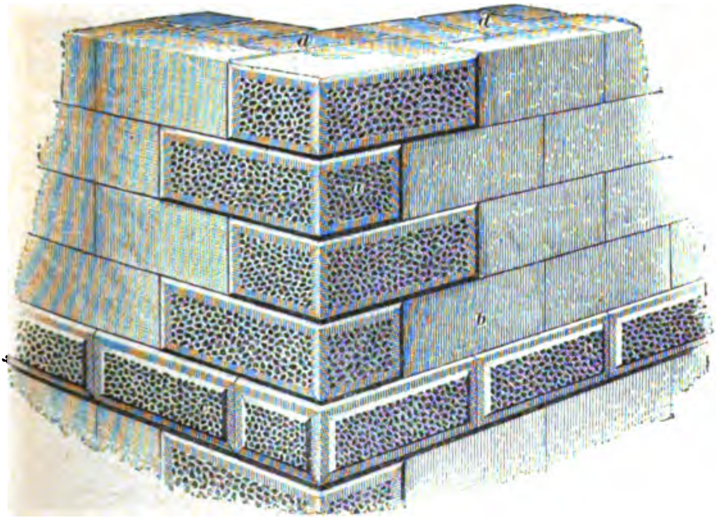


FIG. 10

This class of work is shown in Fig. 9, in which *a* is a 14-inch course; *b*, a 6-inch course; and *c*, the backing. The latter may also be brick, as the ashlar can be well bonded into it. If the narrow band course *b* is rock-faced, or has some different finish than the wide courses *a*, the appearance of the work will be further improved.

15. The stonework of many public and office buildings has rustic quoins and base or band courses, as shown in Fig. 10. Here, *a* indicates the quoins, having a 1-inch bevel, or chamfer, at the joints; *b*, the plain, rubbed, or tooled stones forming the face of the wall; *c*, the rustic band course, having a 1½-inch chamfer cut on it, so as to project beyond the quoins; and *d*, *d*, the stone or brick backing. This method of construction is very expensive, owing to the great amount of dressing required.

16. Block-In-Course Ashlar.—In **block-in-course, or blocked course, ashlar work,** all blocks of stone are cut the same height but in different lengths, and no attempt is made to have the joints come over one another. The length on the face is usually two or three times the height, and about one-fifth of the face should show headers, as at *a*, *a*, Fig. 11. These headers should rest on long stretchers below them, in order that the wall may be better bonded. As a rule, this style of work looks best in rock-faced finish, but any finish desired may be used. Many quarries have stratified stone that are just the proper thickness for this class of work, but unless the stone can be found in such shape, block-in-course ashlar work is generally quite expensive.

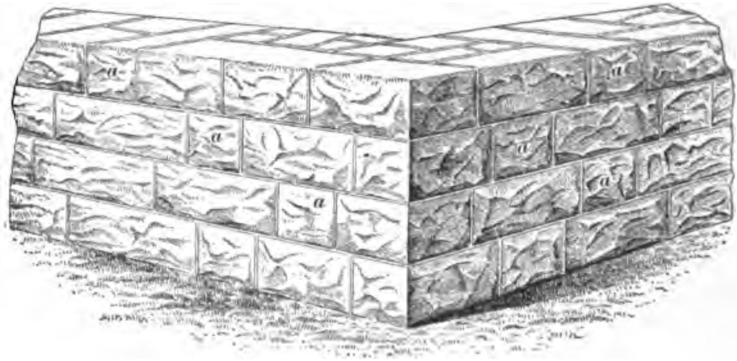


FIG. 11

17. Random-Coursed Ashlar.—The method of laying **random-coursed ashlar walls** is illustrated in Fig. 12. In this class of work, no attempt is made to have the vertical joints over one another, and it has only a general arrangement in courses, as shown.

In regard to the best methods of proportioning the blocks and arranging the same so as to produce a harmonious effect, it is first necessary to consider what the various heights of the blocks must be in order to form good longitudinal bond. Assume the lowest heights at 4 inches—as a stone any thinner than this presents an appearance of weakness—and the greatest height at 16 inches—as any higher than this looks too heavy for random-coursed ashlar. The gradations may then be 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, and 16 inches; thus giving eleven distinct heights—a variety that, when well arranged, produces a most pleasing effect.

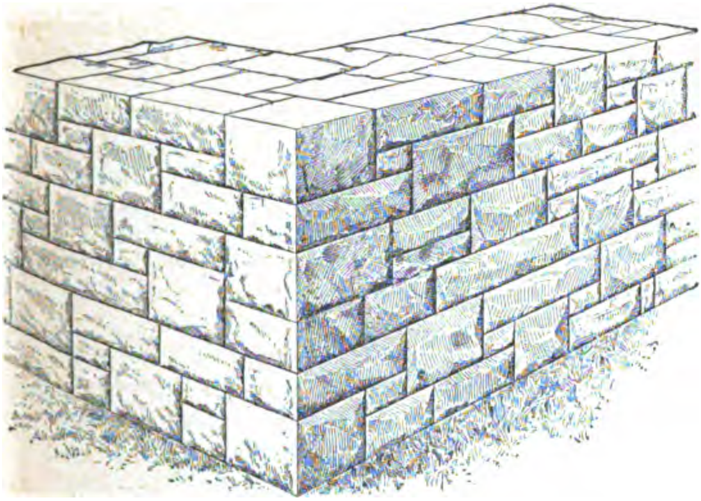


FIG. 12

If the three highest numbers are taken as *jumpers*, or course levelers, the other numbers will agree with them as follows: Take, first, 16 inches as the jumper: 4 + 5 + 7 = 16; 4 + 6 + 6 = 16; 4 + 12 = 16; 5 + 11 = 16; 7 + 9 = 16; 6 + 10 = 16; 8 + 8 = 16; in all, seven possible arrangements. Again, take 14 inches as a jumper: 4 + 10 = 14; 5 + 9 = 14; 6 + 8 = 14; 7 + 7 = 14; 5 + 5 + 4 = 14; or five arrangements; take 12 inches as a jumper: 4 + 8 = 12; 5 + 7 = 12; 6 + 6 = 12; 4 + 4 + 4 = 12; or four arrangements.

The next point to be considered is the lengths of the blocks. The bond, or the lap of the stones over one another, should be, for the thinner blocks, at least 6 inches, and for the thicker ones, 8 inches.

18. Broken Ashlar.—In **broken-ashlar stonework,** no attempt is made to have the stone run in courses, but each block is cut for the location in which it is to go. It generally takes more time to build broken ashlar than coursed work, and hence it is more costly, owing to the increased amount of labor required to fit and lay the different sizes of stone. This kind of ashlar, when properly executed, presents a pleasing appearance. It is generally laid up as rock-faced work, but in some cases, it is tooled or hammer-dressed. It should have no horizontal joints more than 4 feet long, and several sizes of stone should be used. Fig. 13 shows an ordinary broken-ashlar wall, 2 feet thick, the sizes of stones used being 4, 6, 8, and 12 inches in height; *a* shows the quoins and *b* the different sizes of ashlar.

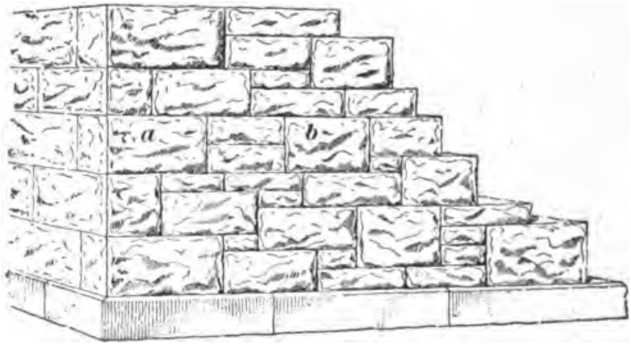


FIG. 13

19. Cutting Ashlar.—In cutting ashlar for first-class work, no stone should have a smaller width of bed than its height, and the larger stones used as jumpers should also be worked in as headers or binders, and should be quarried accordingly. The thinner stones should not be narrower than 8 inches on their beds; otherwise, the facing in some parts will be too light. All the beds of the various widths should be cut true to the square, or the width of bed will be of little value; the backs should also be roughly cut to a true line for the purpose of having the work solidly built, as pinning up and packing in large quantities of spalls is, to say the least, poor practice, and should not be permitted.

The vertical joints may be cut a "little slack" to the square on the back, thus forming a dovetail of the mortar; but the greatest care should be taken to cut the level beds true, so as to prevent rain water from soaking into the wall.

If, where the headers are placed, the interior beds of brick or rubble do not come exactly together with the facework, the best remedy is to have on hand a quantity of bluestone slips that can be used as levelers. No headers for good work should be shorter than 16 inches on bed, and the headers should be placed from 4 to 6 feet apart in each course.

20. **Dressing Ashlar.**—In dressing ashlar, the first finish to be considered is the plain rock face, which, although the simplest, is not the least effective. The block must first be cut true and square all around, forming beds and vertical joints, after which straight lines are drawn around the edges, about 2 inches from the face of the block, and made perfectly out of wind with one another. Then a wide pitching tool is used to cut along these lines, knocking off the surplus material and leaving the face free from tool marks. If, however, the block is very large on the face, it is sometimes necessary to regulate this face by using a pointed tool, working from the center outwards, and obliterating the tool marks as the work proceeds. When finished, the face should have a somewhat regular broken appearance, with about 2-inch projections from the setting arris. Sometimes, window and door openings are left rock-faced in the reveal, but such practice leaves the lines of these openings too undefined and unshapely. It is considered that the best method is to cut the reveals clean in all openings, and finish with either an ax or a bush hammer. The regular band courses should also be clean cut, as by so doing the surface is broken up much better and the rock-faced work is shown off by contrast.

21. The second method of dressing ashlar consists in cutting a margin draft—about $1\frac{1}{2}$ inches wide and neatly axed or droved—around the face of all the openings, and also a margin draft, about $\frac{3}{4}$ inch wide, around every stone. This entails a great deal of labor, however, and its appearance does not justify the cost. It is better adapted for regular coursed work.

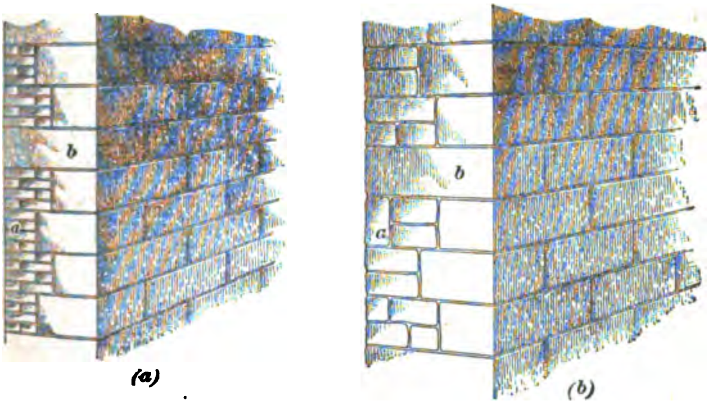
22. **Best Stone for Ashlar.**—The hardest kinds of rock are best suited for ashlar masonry, as, in pitching, the spalls fly off more easily and leave the fracture in sharp lines, whereas with the softer kinds of rock, the fracture has a bruised and crushed appearance, which is not at all pleasing. The best stones to use are the granites and the most compact bluestones and sandstones.

23. **Laying Out Ashlar.**—If ashlar in regular courses and sizes is to be used, drawings should be made showing each different-sized stone, the heights of the courses, and other necessary details. The drawings for public and office buildings usually show every stone, unless broken ashlar is used, in which case it is only necessary to show the quoins and jambs on the drawings, together with enough of the ashlar to indicate the character of the work desired. It is almost impossible to carefully follow a drawing showing all the stones laid as broken ashlar.

24. **Backing.**—The expense of ashlar masonry is such that it is commonly used merely as a facing, being backed with either rubble masonry or brickwork. It is only on works of great importance and solidity that it is used throughout the whole thickness of the wall. In general, the term "ashlar" applies to the facing, or veneering, of stone, or to the stones that constitute the facing.

Both stone and brick are used for backing, but in most cases brick is the cheaper, and, hence, is more extensively used. When using brick for the backing, the joints should be made as thin as possible, employing cement mortar so as to avoid shrinkage, and this backing should never be less than 8 inches thick.

When a hard laminated stone with flat parallel beds can be obtained, it should be used, as it is considered to be a stronger backing than brick. Irregular rubble walls should not be used for dwellings higher than two or three stories, unless the walls are made at least one-fourth thicker than when brick backing is used. All backing, whether of brick or stone, should be carried up at the same time and built in courses of the same thickness as the ashlar. This is illustrated at *a* in Fig. 14 (*a*) and (*b*).



(a) (b)

Fig. 14

If the courses are not over 12 inches high, they are usually bonded sufficiently to the backing by making every other course thicker, and by having one through bond stone to every 10 square feet of wall, as shown at *b* in Fig. 14 (*a*) and (*b*). This method is called a *toothed bonding*.

25. Fastening Thin Ashlar.—Although not so strong as a toothed bond, an ashlar facing of from 2 to 4 inches in thickness is often used, especially when marble or other expensive stones are employed in the construction. In such cases, each piece of ashlar should be tied to the backing by

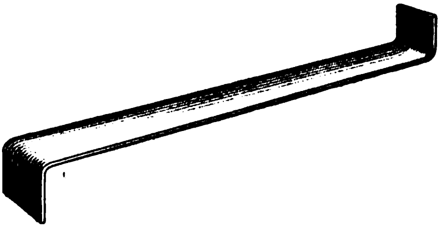


Fig. 15

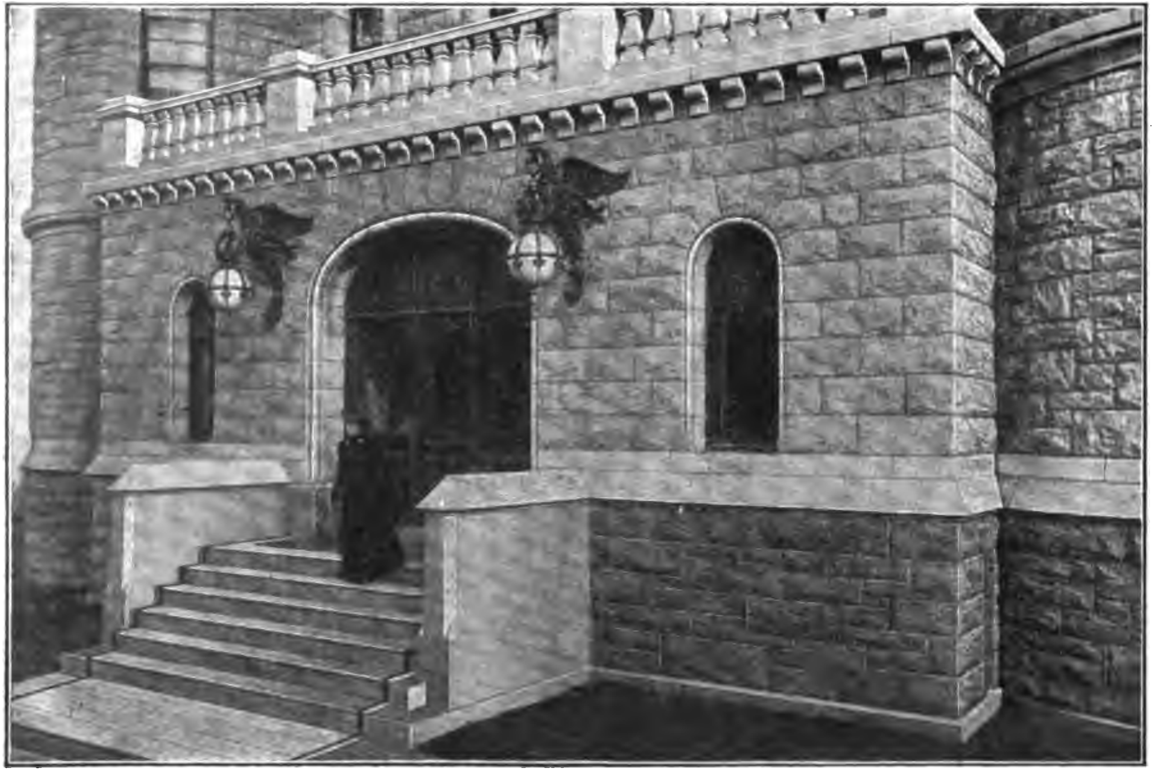


FIG. 16

at least one iron clamp, or anchor, similar to that shown in Fig. 15, while if the stones are more than 3 feet long, two anchors are generally used. All iron clamps, or anchors, should be either galvanized or dipped in hot tar or asphalt, to prevent the formation of rust on them.

Belt courses extending 8 inches or more into the wall should also be laid about every 6 feet in height to give support to the ashlar. When a wall is faced with thin ashlar, the effective bearing strength is only that given by the thickness of the brick or stone backing, the facing not being relied on for that purpose.

26. Ashlar Bonding.—When two kinds of ashlar are to be bonded together particular care should be taken to see that the various courses are brought to the right height. In Fig. 16 is shown an example of a building where the main part is constructed of coursed ashlar and the two towers at the corners are built of broken ashlar. These two styles of masonry form an internal bond, which might be called an *inverted corner*. It will be noticed that the courses in the broken ashlar are so arranged that they come level with the joints in the coursed ashlar, thus permitting the two parts of the building to be toothed, or bonded, together.

SPECIAL STONES

27. Bond Stones and Templets.—Strictly construed, bond stones and templets are not ashlar; but as more or less dressing is necessary on them, they are considered as being ashlar.

All piers above a certain size require **bond stones** to prevent them from splitting. The course of brick placed underneath should be brought to an exact level to receive the stone; otherwise, the weight above may cause it to crack or become displaced. Only strong stones, such as granite, bluestone, and hard trap rock, should be used, and they should be cut to the full size of the pier.

28. Bearing stones placed under the ends of beams and girders to distribute the weight more evenly on the wall are called **templets.** The pressure per square inch allowed on the brickwork or stonework in the wall under the templet as specified by the building laws of the town in which the building is being erected, governs the size of the templet required, and is usually from 100 to 200 pounds. It is better, however, to make templets too large rather than too small. A hard and tough stone should always be employed, and the usual rule is that the thickness of the stone should be one-third of the smallest surface dimension, except when very large stones are used; but the *least* thickness should be 4 inches. When a wooden girder rests on a templet, a good plan is to place a flat stone *above* the end of the girder, so that the wall will rest on the stone and not on the wood. This is advisable for the reason that when the wood shrinks the settlement may cause cracks in the wall.

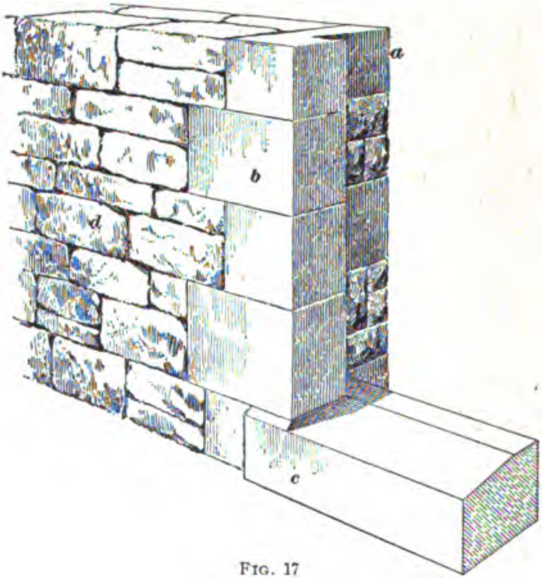


FIG. 17

29. Quoins.—The corner stones of a wall are known as **quoins**, and they are often dressed differently from the other stones in order to make them more prominent. Quoin stones should always be equal in size to the largest stone used in the wall; otherwise, the effect of strength and solidity that they are intended to produce will be lost. Sometimes the quoins in a rubble-stone wall are built of brick.

30. **Jamb Stones.**—The stones in the sides of a door or window opening are called **jamb stones.** The alternate ones should extend through the width of the wall to insure a good bond. Fig. 17 represents cut-stone jambs in a rubble wall: *a* shows the jamb stones bonding into the wall transversely; *b*, those bonding longitudinally; *c*, the stone window sill; and *d*, the rubble wall.

31. Occasionally, when stone piers or pilasters are built on the outside of a building, the windows are recessed so that the projection of the sills and lintels will not be so noticeable. This is shown in Fig. 18, in which *a* shows the lintel; *b*, the sash; and *c*, one of the jamb stones.

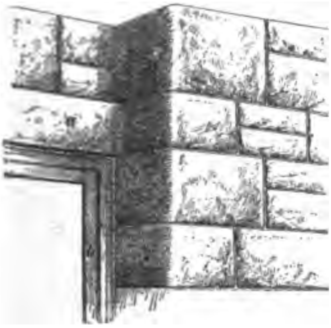


FIG. 18

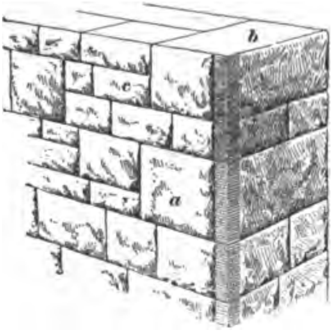


FIG. 19

Jambs and quoins are often finished with a draft, or angle line, especially when the softer stones are used. Fig. 19 shows this method of finishing: *a* indicates the quoin or jamb stone, as the case may be; *b*, the angle draft; and *c*, the broken ashlar wall.

TRIMMINGS

32. The term **trimmings,** as generally used, includes moldings, belt course, sills, caps, and other cut stone (except ashlar) used for ornamental purposes.

The stones for such work should be of good quality, having the beds closely dressed and the ends square and properly matched. The faces may be pitched off, but all washes, soffits, etc. should be cut or rubbed. When a brick building is trimmed with stone, great care should be taken to have the trimmings set properly, so that it will not be necessary to split the courses of brick below or above, for such a procedure will spoil the appearance of the building.

33. Washes and Drips.—The tops of all cornices, belt courses, etc. should have an outward and a downward pitch from the walls, as shown at *b*, Fig. 20. If the top is level or slopes inwards, rain will collect, and in time will cause the disintegration of the mortar in the adjacent joints and finally penetrate the wall. The beveled surfaces are called **washes.** On the under side of the cornices, etc., **drips** should be made, to prevent rain water from flowing down the face of the wall. At *a*, Fig. 20, is shown the drip; at *b*, the wash of the cornice; and at *c*, the stone cut to a sharp angle, to shed part of the water from that edge.

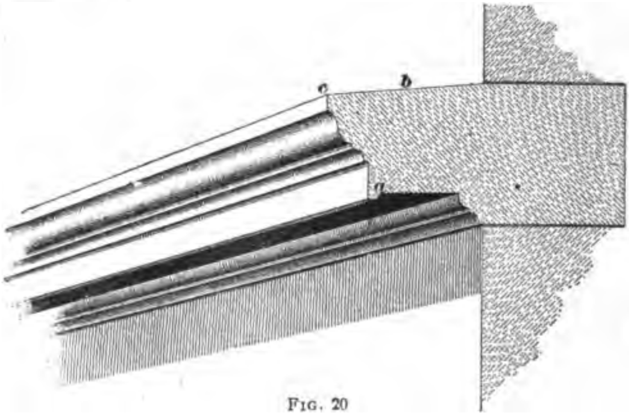


FIG. 20

Window sills should also have a drip cut in them, as shown at *a*, Fig. 21, to keep the walls below from becoming discolored by dirt washed off the sills by rain.

LINTELS

34. A **lintel,** often called a *cap*, is a stone that supports the wall over a door or a window opening; and, as it must resist bending stress, it should be a strong tough stone having an ample cross-section. The ends of stone lintels should not be built into the walls more than is necessary to give sufficient bearing; 4 to 6 inches at each end is the usual allowance. There should be a little play allowed at each end, so that the lintels can yield slightly without cracking if the walls on either side settle unevenly.

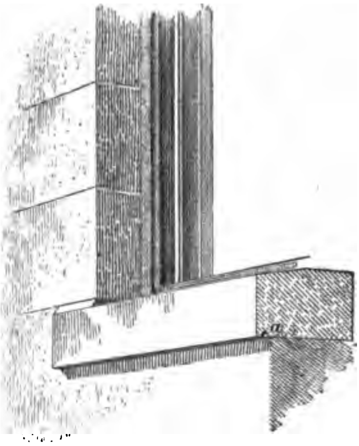


FIG. 21

35. Strength of Lintels.—A lintel acts as a beam, and hence the ordinary beam formulas will apply. For uniformly loaded beams, the breaking load is found as follows:

Rule.—*Multiply twice the breadth, in inches, by the square of the depth, in inches, and also by the proper constant. Divide the product by the span, in feet; the quotient will be the breaking weight for a uniformly loaded beam.*

Expressed as a formula, this rule is:

$$\frac{2 b d^2 A}{L} = W$$

in which
b = breadth, in inches;
d = depth, in inches;
L = span, in feet;
A = constant;
W = breaking load, in pounds.

If the weight is concentrated at the center, the breaking load is $\frac{1}{2}W$ instead of W.

The value of the constant A is, for bluestone, 125; for granite, 100; for limestone, 83; for marble, 103; for slate, 275; and for sandstone, 60.

This formula is practically the same as that given for flagstone in a previous Section, the only difference being that here the breadth of the beam varies.

36. When the weight on a lintel consists of a dead load that is not liable to shocks, such as masonry, one-sixth of the breaking load may be taken as safe. If, however, the lintel is subject to live loads of any kind, not more than one-tenth of the breaking load should be taken. In such cases, it is better to avoid the use of stone lintels, unless reinforced by angles or beams.

As an example, let it be required to find the breaking load of a bluestone lintel 10 inches wide, 24 inches high, and 7 feet long between supports, and uniformly loaded. Using the formula,

$$W = \frac{2 \times 10 \times 24^2 \times 125}{7} = 205{,}714 \text{ pounds}$$

Taking one-sixth of this, gives 34,286 pounds as the safe uniformly distributed load.

37. Relieving Lintels.—Often when a long lintel is used over an opening, the stonework above the lintel is

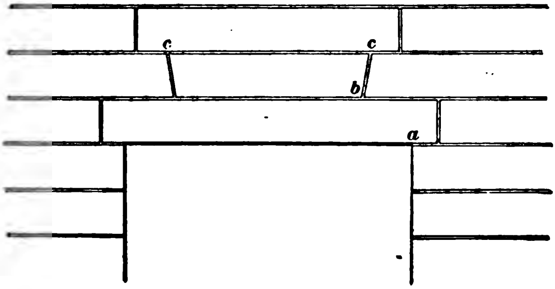


FIG. 22

arranged as shown in Fig. 22, in which a is the lintel, and b the **relieving lintel**, or stone above it cut with two diagonal joints, as at *c*, *c*. In this way, some of the load is taken off the lintel and transferred to the wall on both sides of the opening.

When a lintel extends through the wall and is not supported by angles or beams, the strength may be increased,

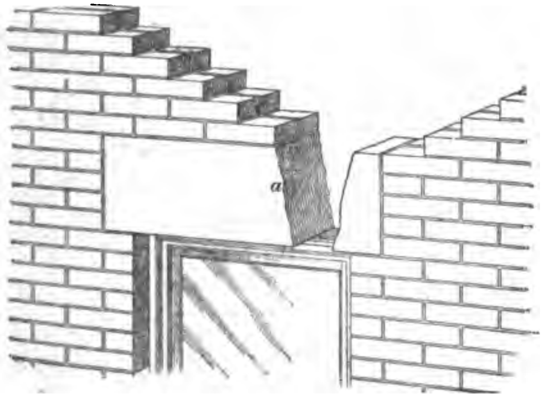


FIG. 23

if the stone is stratified, by cutting it in such a manner that the layers will set on edge, as shown at *a*, Fig. 23. This procedure, however, may cause the face of the lintel to flake off if the layers of stratification are thin and not securely joined together.

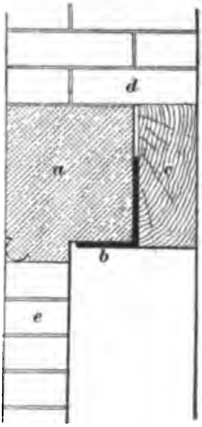


FIG. 24

38. When considerable weight rests on a stone lintel, a brick receiving arch may be used; but unless much skill is exercised, this will detract from the appearance of the building, especially if the arch extends through the entire thickness of the wall. To avoid this result, if stone of sufficient depth cannot be used, the lintel may be strengthened by the use of iron beams or angles. When the lintel is of moderate length, it is sufficient to use a piece of angle iron, as shown in Fig. 24, in which *a* is the stone lintel; *b*, the angle, which should have its longer side vertical; *c*, a wooden beam to which the interior woodwork is nailed; *d*, the brick wall; and *e*, the window reveal.

39. I-Beam Supports.—When the width of the opening is considerable, stone lintels should be supported on **I** beams. If only the weight of the lintel and wall is to be carried, a single **I** beam may be used, as shown in Fig. 25, in which *a* represents the stone lintel; *b*, the **I** beam; *c*, the wooden beam to which the wood finish is attached; *d*, the reveal; and *e*, the brick wall.

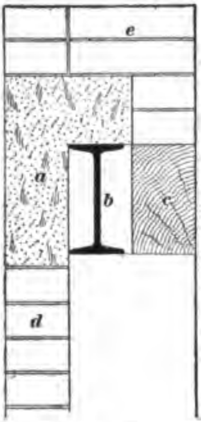


FIG. 25

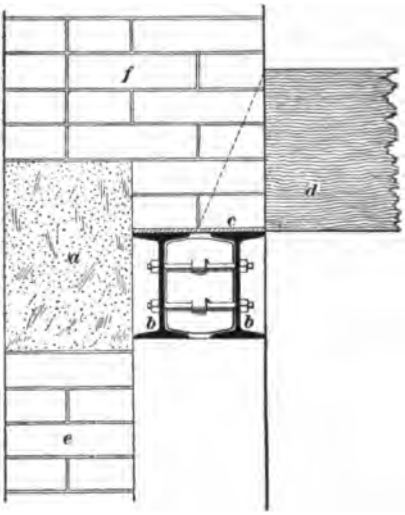


FIG. 26

When, in addition to the walls, the floorbeams over openings must be carried, it is best to use two **I** beams, as shown in Fig. 26, in which *a* is the stone lintel; *b*, *b*, the **I** beams, held together by bolts and separators; *c*, an iron plate on which the wall rests; *d*, a floorbeam; *e*, the window reveal; and *f*, the brick wall.

When it can be avoided, the best plan is not to support the weight of a wall on both stone and steel or wooden beams, as the deflection of each material is different, making it practically impossible for each to carry its proper share of the load. The weight should preferably be borne by the steel beams alone.

40. **Built-Up Lintels.**—It is sometimes necessary to use a stone lintel 10 or 12 feet long, which is difficult to obtain in a single piece. In such a case, the lintel may be made in sections. At least three stones should be used, and the joints should be cut as shown at *a*, *a*, Fig. 27. When cut in this manner the stones are self-supporting. The end-pieces may be built into the wall for a considerable length, so as to act as cantilevers supporting the middle section. If such long lintels are used, however, it is better to carry them on I beams, as shown in Figs. 25 and 26.

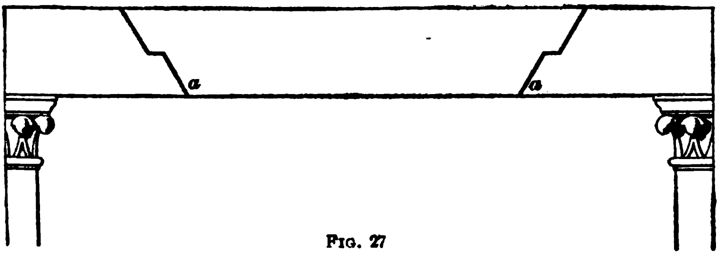


FIG. 27

As it is well, in brickwork, to avoid placing a pier directly on top of the lintel, in stonework, also, try to place all openings directly above one another.

SILLS

41. **Lug and Slip Sills.**—In masonwork, **sill** is the name given to the stones that form the bottom of the window and door openings in stone or brick walls.

Lug sills have flat ends, or *lugs*, built into the wall. These lugs should not enter the walls over 4 inches, and should be bedded on mortar only at the ends. If a sill is bedded solid and settlement occurs, it will probably be fractured at the jamb line, as the pier or side walls will likely settle more than the wall under the opening. The joints under the sills should be filled when the finished walls are cleaned down.

Slip sills are made just the width of the opening, and are not built into the walls, being put in place after the frame is set. Slip sills are cheaper, but do not look so well as lug sills; besides, there are exposed vertical joints at the ends into which water will penetrate. Any settlement of the masonry is not liable to break a slip sill, and hence they are often used in the lower parts of heavy buildings.

42. All sills should have a bevel, or wash, of about 1 inch to the foot, extending to the back of the reveal, as shown in Fig. 28. They sometimes have a straight beveled surface the full length of the sill, the brickwork being made to fit the stone. This, however, is not good practice, as such construction permits water, running down the jamb, to enter the joint between the brick and the stone; the sloping upper face also forms an insecure bearing for the wall resting on it. In Fig. 28 is shown the proper method of cutting the surfaces: *a* indicates the flat end of the lug sill, carrying the brickwork reveal *c*; *b* shows the bevel, or wash; and *d*, the drip.

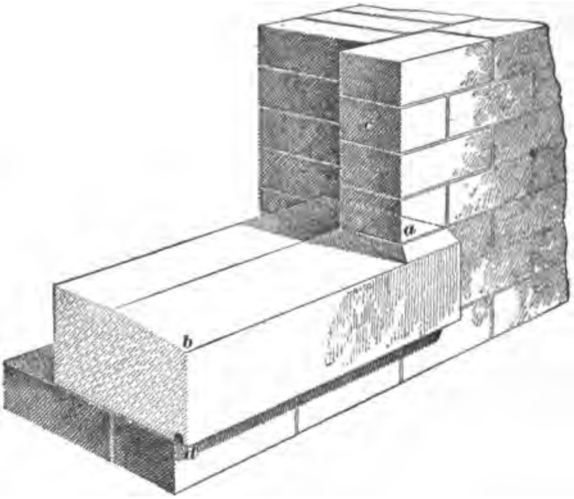


FIG. 28

COPING

43. Coping Stones.—If no cover is put on the top of a wall, rain will wash out the joints between the brick or the stone. For this reason, parapet walls and those constructed in a similar manner are capped with a wide stone called **coping.** Terra cotta is also occasionally used for this purpose. The upper surface of the coping should be pitched, as shown at *a*, Fig. 29, and should have a drip on the under side, as shown at *b*. The coping should be about 3 or 4 inches wider than the wall. Horizontal coping stones are often clamped together at their ends to prevent them from becoming displaced.

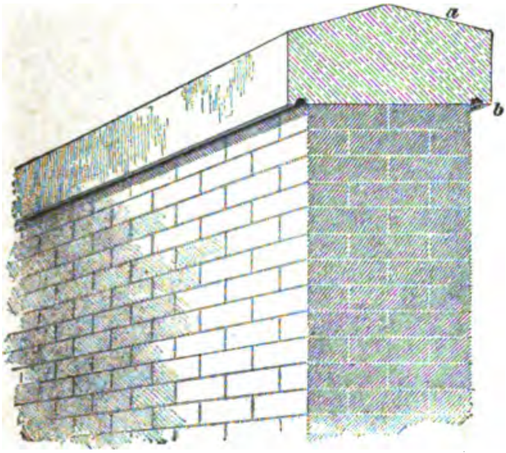


Fig. 29

Gable copings should be anchored either by bond stones or by long iron ties. A form of coping that is considerably used is shown in Fig. 30, in which *a* is the coping; *c*, the corbel; and *b*, the bottom stone, sometimes known as the *kneeler*, which should always be well bonded into the wall. In some cases, the coping is cut in steps, so that each stone will have a horizontal bearing on the wall. This method of coping is objectionable, however, on account of the increased number of joints. It is well to have long pieces of coping, so as to reduce the number of joints—a common length is 6 feet. A short piece cut as shown at *a*, Fig. 31, should be inserted at intervals to securely bond the coping to the wall.

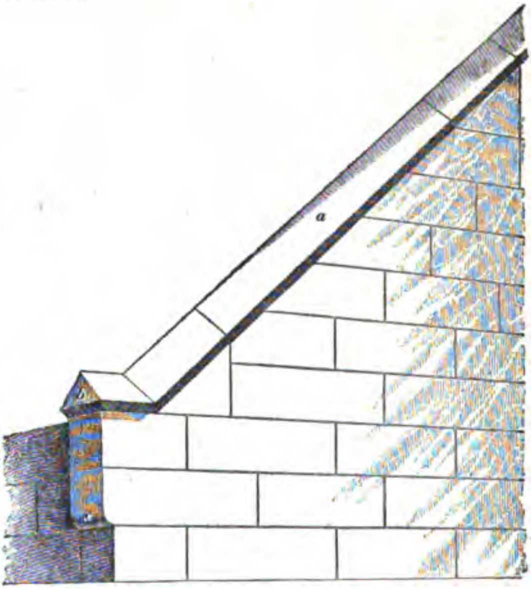


FIG. 30

Gable copings do not necessarily have to be pitched on top, but they should project on both sides of the wall and have a drip at each edge so as to shed the rain water.

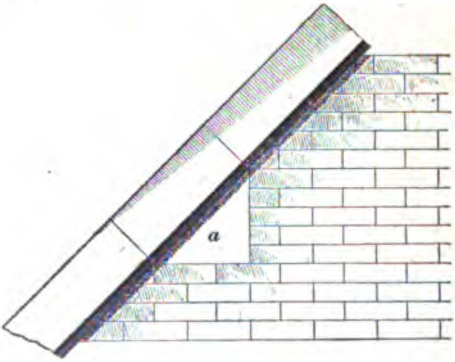


FIG. 31

44. Stone Apexes.—Fig. 32 shows a **stone apex** for a gable on a roof of heavy construction. The apex is cut out of a single piece of stone, and is made with a flat bed so as to rest solidly on the end wall. The two faces are grooved to receive the coping stones, as shown in the illustration. The apex is often secured to the wall by means of iron ties, which are placed inside the building.

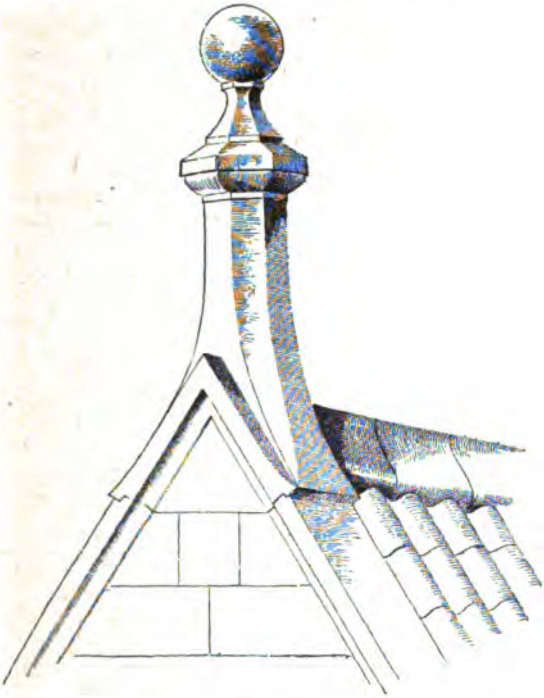


FIG. 32

COLUMNS AND ENTABLATURES

45. Columns.—When possible, it is best to have the shaft of a column formed in one piece, irrespective of length—that is, a *monolite*. All the columns in the latter portion of the Capitol at Washington, District of Columbia, are marble monoliths, quarried in Maryland. For a good class of work, if the column is not over 8 feet in height, the shaft is generally so cut, with the cap and base separate.

When a column is to be formed of several pieces, the stones composing the different parts should be very carefully cut, having the abutting surfaces between the cap, base, and shaft perfectly plane and perpendicular to the axis of the column, in order that the pressure may be evenly distributed over the entire surface of the joints. For the joints, nothing but cement mortar should be used, which should not be allowed to come within $\frac{3}{4}$ inch of the edge of the joint, in order to prevent the edges of the stones from spalling.

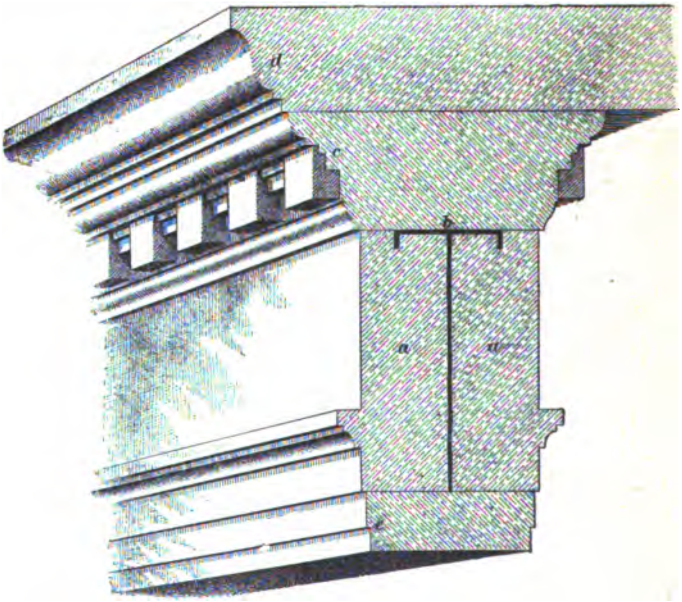


Fig. 33

If the column is built against a wall, thus forming what is called a *pilaster*, the cap and base should be bonded to the wall, either by extending them into it or by securing them to it with galvanized-iron clamps, or anchors.

46. Entablatures.—An **entablature** is that part of the structure which spans a porch, or entrance, opening, and is supported by columns. All the stones composing the entablature should be well tied together with clamps and anchors, particularly at the outer angles. Porch cornices are sometimes tied to the main structure by long rods enclosed in the masonwork, so as to prevent the porch from settling away from the building.

An example of an entablature is shown in Fig. 33, which represents the cornice of a porch. In this figure, *a*, *a* are the two facial stones forming the inside and outside of the entablature; *b*, the iron clamp, or anchor, holding them together; *c*, the lower portion of the cornice, showing the *dentils; d*, the upper part, showing the *corona;* and *e*, the bottom member of the architrave, or lower portion of the entablature.

STONE STEPS

47. In laying steps, it is important to see that they are firmly supported at each end, but are left free in the middle. If the stones forming the steps have a bearing along their entire length, they might, after a slight settlement in the foundations, rock from side to side when stepped upon, or they might crack. In order to strengthen extra-long steps, however, it is sometimes necessary to insert a middle

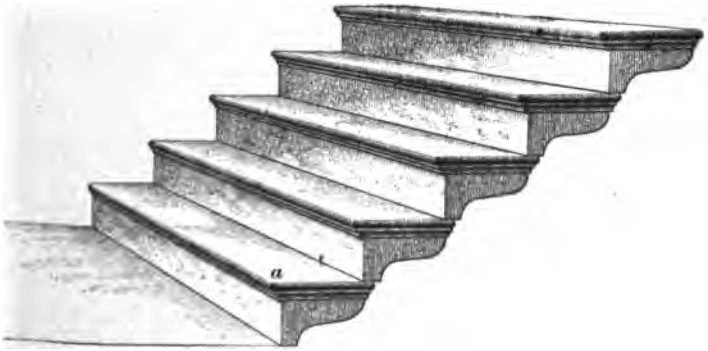


FIG. 34

bearing; great care must then be exercised to have the middle and two end supports exactly on a line. Each step should overlap the one below at least $1\frac{1}{2}$ inches, and should have an outward pitch of about $\frac{1}{8}$ inch. Steps having a nosing, as shown at *a*, Fig. 34, make a good appearance, but are much more expensive than the ordinary ones.

A hard stone, such as granite or bluestone, should be used for steps; but for private residences, where the wear is not great, limestone or a fairly hard sandstone may be employed.

48. Stone stairs are sometimes made with only one end supported. This end is built solidly into the wall, and each step is carried on the next lower one. This construction is shown in Fig. 35, in which *a* represents the landing rabbeted into the tread of the top step, while *b* shows the manner in which each step is cut and supported by the lower one. To be safe, the bearing dimensions should not be less than shown in the illustration. The bottom step should be firmly held in place by dowels set into the floor, as shown at *c*, as this step must sustain the thrust of the whole flight. The stone blocks forming the steps are usually cut in the triangular cross-section shown, which method of cutting gives a good appearance to the soffit, or ramp, of the stairs.

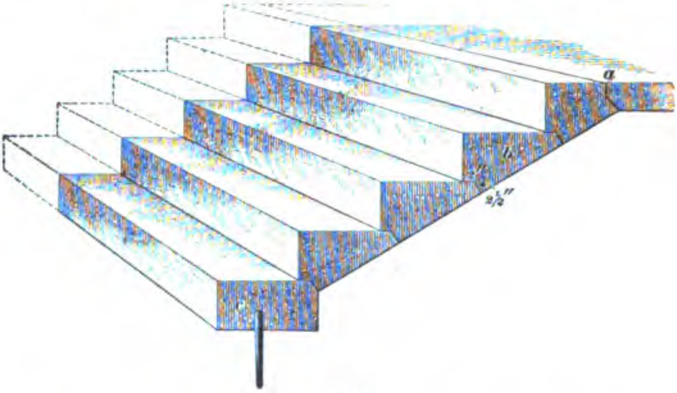


FIG. 35

49. Iron staircases are very extensively used in fireproof construction. The treads, and sometimes the risers, are marble slabs, while slate, being cheaper, is also considerably used. Staircase railings for stairways having stone or iron steps are often elaborately finished, and are generally made of iron, which is doweled into the ends of the steps.

MASONRY DETAILS

CARE OF STONEWORK

50. Pointing.—The effects of the weather on the exposed edges of the joints in masonry usually cause the mortar to crumble and fall out. For this reason, it is customary to refill the joints to a depth of from ½ to 1 inch, with specially prepared mortar. This operation is called **pointing.**

Pointing is generally done as soon as the walls are completed, but, if the season is too far advanced, it should be deferred until spring. Under no circumstances should it be done in freezing weather, nor in extremely hot weather, as then the mortar will dry too rapidly. The most durable mortar for pointing is made of equal parts of Portland cement and sand, adding such coloring matter as may be desired, and mixing with just enough water to give a plastic consistency.

51. To point a joint, first rake out the old mortar to a depth of about ¾ inch, and clean the joint thoroughly with a wire brush. The joint should then be made wet so that the pointing mortar will adhere to the stone, after which the mortar is applied with a

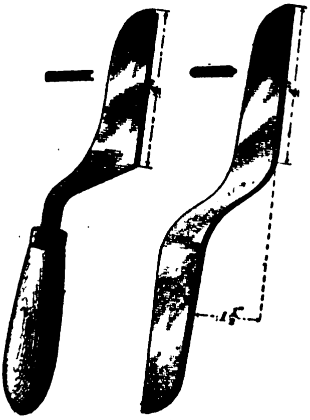

(a) (b)

FIG. 36

pointing trowel, and thoroughly pressed in and given a smooth surface with a tool called a *jointer*.

In Fig. 36 (*a*) is shown a concave-edged jointer, and at (*b*), a convex-edged jointer. It will be seen that the jointer gives either a raised or a sunken joint, as may be desired. The latter is the more durable joint, but the first makes the better looking job.

The different forms of pointing are shown in Fig. 37, in which *a* indicates the concave joint; *b*, the convex; and *c*, the convex projecting beyond the face of the stone.

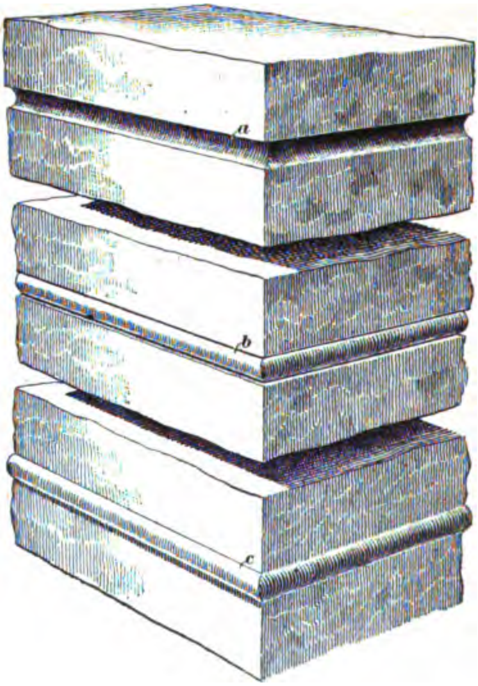


Fig. 37

52. Cleaning.—After pointing, it is usually necessary to remove the mortar stains, etc. from the face of the wall. This may be done by scrubbing the stonework with a brush dipped in water containing muriatic acid, the proportions being about twenty parts of water to one part of acid. For cleaning granite and limestone, wire brushes are used, and for sandstones and other soft stones, stiff bristle brushes usually serve the purpose. The stonework should be scrubbed until all mortar stains are removed.

The sand blast, worked by either steam or compressed air, does the work of cleaning walls very effectively and rapidly; it removes the outer layer of the discolored stone, and leaves a fresh, bright surface. Even fine carvings have been very successfully cleaned by this method.

53. **Protecting Stonework.**—The durability of masonry may be somewhat increased by covering the exposed surfaces with a preservative, but of the many preparations for protecting stonework none is cheap or satisfactory.

Lead-and-oil paint is the most generally used for this purpose, but, while it may be temporarily effective, it spoils the appearance of the stonework and requires frequent renewals, owing to the action of rain and other atmospheric influences.

Boiled linseed oil is also sometimes used, but it darkens the color of the stone. To apply the oil, the surface of the stone is first washed clean and dried; the wall is then covered with one or more coats of oil, and finally washed with weak ammonia, which makes the coloring more even. Oil thus applied will last 4 or 5 years.

Another preparation consists of paraffin, mixed with creosote, the whole being dissolved in turpentine. The purpose of the creosote is to prevent vegetable growths on the stone. Before applying the preparation, the stone should be heated; the melted compound is then applied with a brush. It will penetrate some kinds of stone to a depth of ½ inch.

54. Sylvester's process consists in the application of two washes, the first composed of a hot solution of Castile soap in water, and the second of alum water, which is applied about 24 hours after the soap solution. This process has been found more or less successful when the stone is not subjected to great variations of temperature.

Another method, known as Ransome's process, has been used in England with good results, and consists in applying a solution of silicate of soda or potash to the clean surface of the stone until it is thoroughly saturated. When this has dried, a solution of chloride of calcium is applied, the effect of which is to produce an insoluble silicate of lime, thus forming a waterproof coating.

STRENGTH OF MASONRY

55. In Table I are given the safe loads that different classes of masonry will sustain.

TABLE I

STRENGTH OF MASONRY

Kind of Masonry	Load per Square Inch Pounds
Rubble sandstone, in lime mortar	80
Rubble limestone, in lime mortar	80
Bricks, hard, in lime mortar	100
Bricks, hard, in Rosendale-cement mortar	150
Rubble limestone, in cement mortar	150
Rubble sandstone, in cement mortar	150
Squared sandstone	175
Bricks, hard, in Portland-cement mortar	200
Concrete, 1–2–4 Portland cement	300
Squared granite	350
Sandstone capstone	350
Limestone capstone	500
Granite capstone	700

56. A column of good stone that is carefully set and has well-dressed bearing surfaces should, if its height is not over ten times its diameter, safely carry a load about one-fifteenth of the breaking load of stone of the same quality.

Table II gives the safe bearing values for different kinds of stone columns when the shaft consists of a single piece.

57. A column should not carry a greater weight than 40 tons to the square foot, for, while the stone itself might carry much more, the mortar joint is the weaker part, and hence is most likely to fail. When a column is loaded with over 15 tons to the square foot, it should be set in Portland-cement mortar made of equal parts of cement and sand. This mortar should be laid within 1 inch of the face, so that when the building is finished and the mortar has thoroughly set, the joints may be pointed without raking them out. If a column consists of several pieces, the joints should not exceed $\frac{3}{16}$ inch in thickness, and the bed surfaces should be very finely dressed, perfectly true, and perpendicular to the axis of the column.

TABLE II

SAFE LOADS ON STONE COLUMNS

Kind of Stone	Load per Square Foot Tons
Sandstones—	
Potsdam, New York, best	40
Longmeadow, Massachusetts, best	35
Manitou, Colorado, best	25 to 30
Ohio	25
Fond du Lac, Wisconsin	25
Limestones—	
Glens Falls, New York	35
Indiana	25 to 35
Marble—	
Good quality	40

MEASUREMENT OF STONEWORK

58. Dimension Stone and Rubble.—At the quarry, stone is divided into two classes: *dimension stone* and *rubble*. **Dimension stone** consists of those pieces that are quarried in regular shapes, and to a fixed size; they are usually 4 square feet or more in area and over 8 inches thick. This class of stone is usually sold by the cubic foot, and costs about three or four times as much as rubble.

Rubble includes pieces of various sizes and shapes that form the waste in quarrying the larger stones. It is suitable for work in which the courses are 12 inches or less in height and the stones are not over 24 inches long. Generally speaking, all stone not quarried to a certain size may be termed rubble. Rubble stone is usually sold by the carload, or in small quantities by the perch, and in some localities by the ton.

59. Measuring Methods.—The methods of measuring stone are very unsatisfactory, owing to the great difference in practice in various parts of the country. Dimension-stone footings are generally measured by the square foot. If built of large rubble, or irregular stones, the footings are usually figured in with the walls, with allowance for the extra width. Rubble is usually measured by the perch, which, unfortunately, varies from 16 to 25 cubic feet, being 24¾ cubic feet in the Eastern States, 16⅔ feet, by custom, in Colorado, and from 22 to 25 cubic feet in various other places. A necessary precaution to prevent disputes when work is to be measured by the perch is to agree on the number of cubic feet in a perch, and also in regard to deductions for openings. If this is not done, the custom of the particular locality will probably govern in case of disagreement. In some places, rubble work is measured by the cubic yard of 27 cubic feet or by the cord of 128 cubic feet. Stone backing is commonly figured the same as rubble.

60. Ashlar masonry is almost invariably measured by the square foot, the cost depending on the kind of work and the size of the stones. It is usual to deduct openings in ashlar work; when the width of the jambs of windows is more than the depth of the ashlar, the jambs are usually measured in with the facework. Flagging and all thin pieces or slabs are also figured by the square foot.

Moldings, belt courses, and cornices are usually measured by the lineal foot, but if the shapes are not regular they are figured by the cubic foot. All carved work is estimated by the piece.

Trimmings are sometimes figured by the cubic foot, the price varying with the amount of labor required in dressing. Probably the most accurate way of figuring this class of work is to first estimate the value of the rough stone and then that of the labor involved in the different classes of work, the resulting prices being per lineal foot. This method is the one usually employed in figuring granite work.

INSPECTION

61. The inspector or superintendent should be very careful to have the work properly done during erection, both in cutting and setting stone, for if an imperfect piece is once set in place it cannot be removed without considerable trouble. The stones must also be carefully examined, as otherwise many cracked and defective ones may be used, either by accident or design.

62. Stone Defects.—Granite may contain cracks, black or white lumps known as *knots*, and a brownish stain called *sap*. When such defects are found, the stone should be rejected, if the importance of the work justifies it. Cracks are the main things to guard against, however, and they may be detected by the absence of the clear ringing sound when the stone is struck with a hammer.

Sand holes are frequently found in sandstones. These are bodies of uncemented sand that become dislodged by jarring or by the action of water and produce a pitted appearance and an uneven color. Attention must also be paid to securing uniformity of color, as sandstone from different parts of the same quarry may vary greatly in this respect.

63. Patching.—**Patching** is often resorted to when a piece has been broken from a stone. Instead of using a new stone, the old one is patched by gluing on the spall with shellac, the joint being hidden by rubbing stone dust over it. Rain, however, will wash out the shellac. There are times when a patch is allowable, as, for example, when a new stone cannot be had without great expense and delay. In such a case, the superintendent may permit patching to be done, but care should be taken to put on the spall by inserting it, when possible, in a square hole, or dovetailing it in such a way that it will not become displaced.

64. Faults in Dressing Stone.—The common faults of cut stone are coarseness and poor workmanship. In dressing stone, builders will avoid any work beyond that necessary to make the material barely acceptable to the inspector.

Frequently, the ends of cornices, belt courses, etc. will not properly match. It should be strictly required that the utmost care be taken in cutting all similar pieces to the same pattern, and that the abutting surfaces be closely dressed.

65. Laying Stonework.—In erecting stonework, care should be exercised to have the stone set on the natural bed, with good joints, and not in too small nor in too thin pieces. The bed joints in ashlar work should be square to the face of the work, and not less than 4 inches wide at both top and bottom. The proper bonding of the walls, especially for the ashlar and for the trimmings, should be given very careful attention, as well as the placing of lintels, copings, wall anchors, etc.

Another point that requires attention is the formation of the joints on which great pressure comes; the mortar should be kept back from the face, so that the edges of the stones will not be chipped off. Also, in pointing, the joints should be well raked out and the pointing mortar properly laid. Many other precautions for the good performance of the work will doubtless suggest themselves to the careful superintendent.

STONE ARCHES

ARCHES AND ARCH CONSTRUCTION

INTRODUCTION

1. The origin of the stone arch is lost in antiquity. In the ancient city of Nippur, unearthed in recent years by the excavation of explorers, are found the remains of sewers whose tops were built of rough stones in the form of arches. Just when these arched drains were built is not known, but they certainly dated back many centuries before the Christian era. It was not, however, until during the rise of the Roman Empire that the arch came into use as an architectural feature, and ever since then it has been employed more or less in building construction. Today the arch is not used as much as in former years, owing to the expense of building and the extensive employment of steel beams to span large openings.

2. Historical Examples.—The medieval architects used the arch very extensively, as will be seen from Figs. 1 and 2, which are examples given by Viollet-le-Duc, the celebrated French architect, in his famous writings. In Fig. 1 is shown the keep in the Château de Coucy built by Enguerrand III in the year 1225. Here, all openings are spanned by arches, and the floors are supported by groined arches, as shown. The niches in the lower story are divided into halves by arches, as shown at *a*, *a*, the lower part being used

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for storage, while the upper part, extending into long narrow openings in the outer wall, are used for light and defense in time of war. The wall at the base is almost 18 feet thick. In the third story, the wall is made thinner, and thus forms a balcony, shown at *b*, which enabled a large number of people to assemble on that floor. It will be particularly noted that all the large openings are spanned by arches.

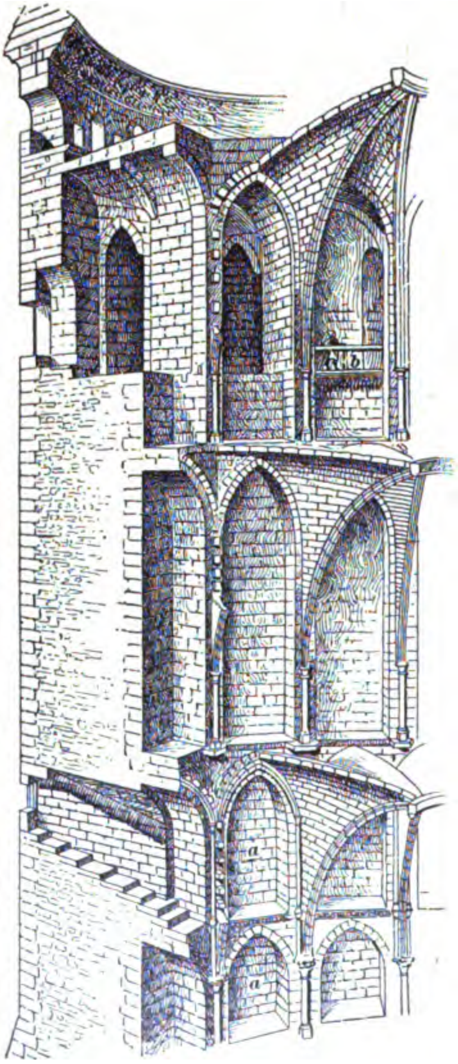

Fig. 1

3. The example shown in Fig. 2 is a medieval house. The passages that give access to the various rooms are galleries on the outside of the building. These galleries, however, are of such a height as to admit air and light above them, and are supported by piers, or buttresses, which have arches sprung between them, as shown. The floor, however, is not supported by arches as in Fig. 1, but by wooden beams. The roof is also of wood, and is built on a steep pitch, as was the custom in those days.

4. Utility of Arches.—Stone arches are used in both stone and brick structures, but in some ways a stone arch is not as satisfactory as a brick one. Being composed of a few large pieces instead of many small ones—as is a brick arch—the bond is not so perfect; and, consequently, of the two, the stone arch is somewhat more liable to settle and crack.

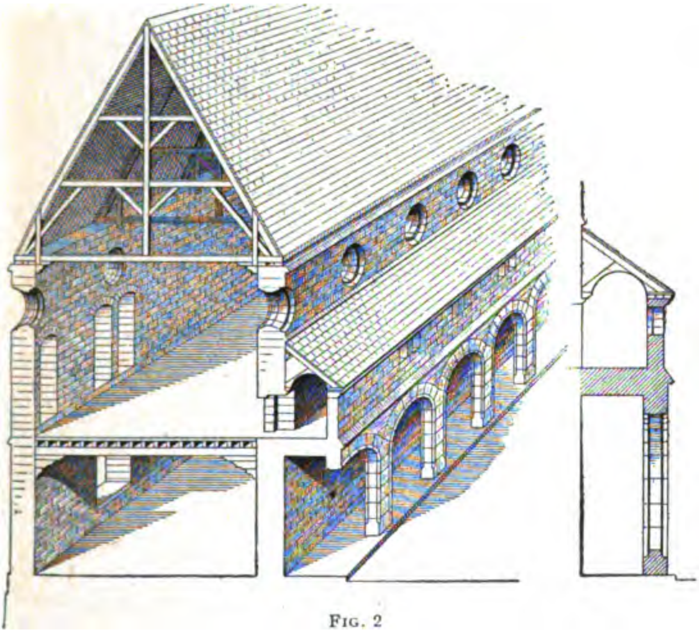

FIG. 2

The amount of masonry in heavy piers, etc, can, without injuring the stability of the structure, often be considerably diminished by the use of arches, provided the stone and the footings are capable of carrying the increased load. If necessary, the pressure on the soil may be distributed by using inverted arches.

5. Names of Stones Used in Arches.—In Fig. 3 is shown a stone arch. In this arch the *skewbacks* b, b and *ring* *stones*, or *voussoirs*, *c*, *c* are of the same size on the face. These are sometimes made of varying sizes, but in any case the depth (back into the wall) should vary as much as may be necessary for proper bonding. The *abutments* are the piers from which the arch springs, as shown at *a*, *a*.

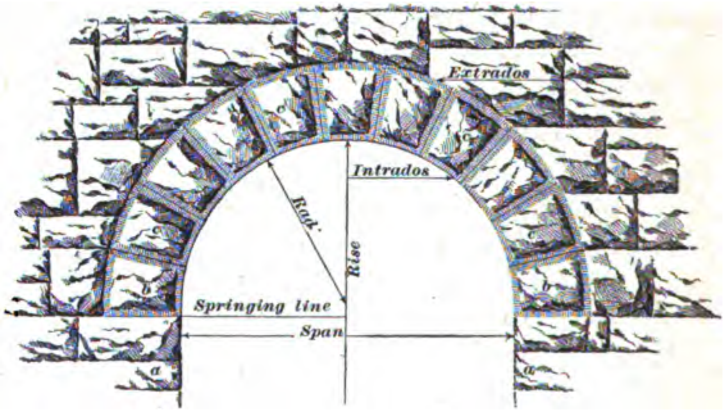

FIG. 3

6. Stability of Arches.—In building construction it is not customary to determine the proportions of arches of small span by calculation. The appearance is often the controlling factor in designing such arches. But when the arches are of considerable span, the position of the *line of resistance* should be determined. As that is somewhat beyond the scope of this Section, merely the conditions necessary for stability will be here mentioned.

In relation to arches for engineering purposes, the well-known authority, Professor Rankine, says: "The best course in practice is to assume a depth for the keystone based on the dimensions of good existing examples." This statement holds good in connection with the construction of the arches that an architect ordinarily has to design.

Having fixed the depth of the keystone, the voussoirs are all made the same height in arches of small span, while in longer ones the ring stones vary in depth, increasing gradually from the crown to the skewbacks, so as to preserve a uniform pressure on the stones as the load becomes greater.

7. To insure the stability of an arch, there are two conditions besides the one just mentioned that must be satisfied. One is that the pressure shall not cause the opening of the joints; the other, that the direction of the pressure shall not be such as to cause one ring stone to slide on another.

These requirements are met by making the arch ring of proper depth, and generally do not need to be determined theoretically for small arches, and are left to the structural engineer.

8. Flat arches—those having but little rise—give way by breaking in the four parts, opening at the crown of the intrados and at some joint on the extrados. When a flat arch breaks, the two upper parts fall inwards and press the lower parts outwards. In pointed arches, the reverse is the case, the lower portions tending to fall into the opening and to force the upper parts outwards.

KIND OF ARCHES

9. Arches are frequently named from the curve of the intrados, as *semicircular*, *segmental*, *semielliptic*, *pointed*, etc. They are also sometimes named from the period in history in which they were most used, as the *Tudor arch*, or from a nation that devised them, as the *Moorish arch*.

10. **Early Arches.** The arch shown in Fig. 4 is an old and primitive form of arch. It is probably the first form of arch ever built, and is therefore the starting point of all arch construction. It possesses several disadvantages however. Being composed of only

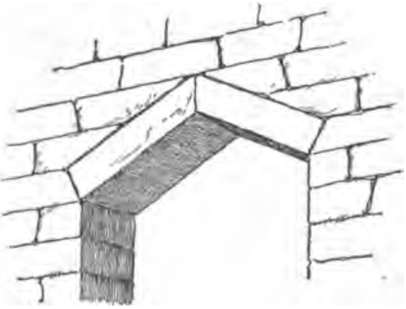

Fig. 4

two stones, these stones are subjected to transverse stress as well as to direct compression. As bending will cause tension on the under side of the stone, and as most stones are weaker in tension than in compression, it follows that this arch may fail by bending instead of by direct compression. For this reason the arch is not applicable to long spans.

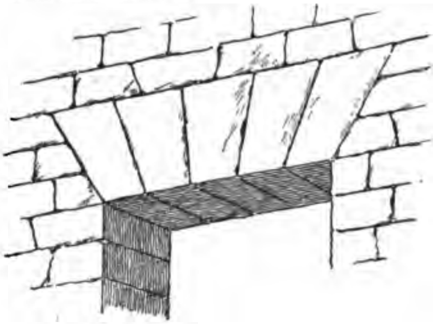

FIG. 5

11. Flat Arches. The arch shown in Fig. 5 is known as a **flat arch,** and while not chronologically next in order to the arch shown in Fig. 4, it perhaps follows in simplicity of design. This style of arch is used extensively over windows and other short spans where a flat soffit is desired, and very often in brick buildings. It will be noticed that all the voussoirs are wedge-shaped and that it would be difficult to force one down out of its place. Although called a flat arch, it is usually built with a rise of $\frac{1}{8}$ inch per foot of span. This is to allow for any settlement that might occur while the mortar is setting.

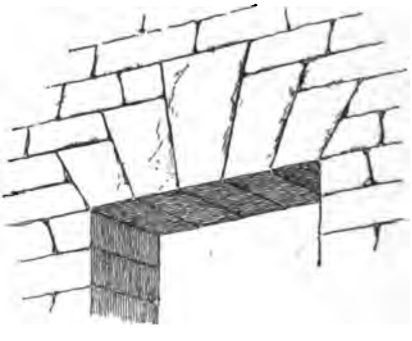

FIG. 6

12. Fig. 6 shows another style of flat arch more ornate than the one shown in Fig. 5, but different from it only in that the voussoirs are of different sizes.

Many other styles of flat arch are used in practice, but they are all built on the same principle as the ones just described.

13. When an arch is so flat as to have practically no rise, it often is cut out of one piece of stone, being really a solid lintel with false joints cut on its face, as shown at *a*, *a*, Fig. 7. The ends of this lintel should have a bearing of 4 or 5 inches on the wall, as indicated by the dotted lines *b*, *b*.

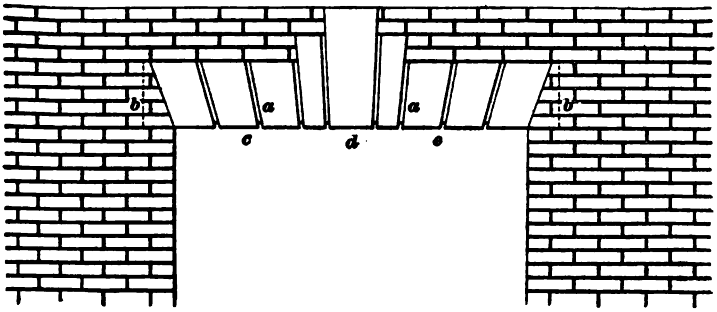

FIG. 7

If the walls are of brick, about 2 inches of the front of the stone may be cut away and faced with brick. If this method is too costly, the lintel may be cut into three pieces, as at *c*, *d*, and *e*, and supported by a heavy angle bar.

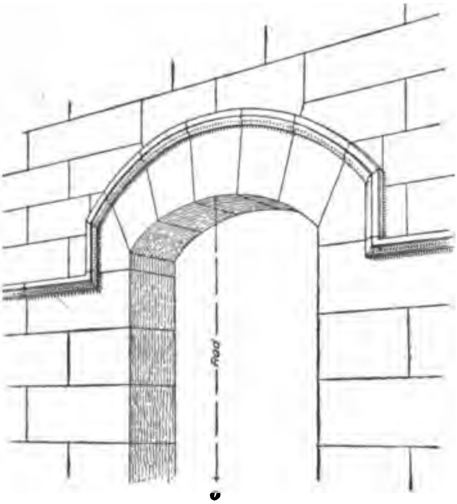

FIG. 8

14. Segmental Arches.—If the rise of a flat arch is increased, the arch will look like the one shown in Fig. 8, which is called a **segmental arch.** The curve of the intrados is struck from a center, as at *o*. The point *o* is always below the springing line in an arch of this character, and the radius of curvature of the intrados is always greater than one-half the span. The arc of the extrados is usually struck from the same center as the intrados, although any other form of design may be carried out.

15. Circular Arches.—When the center of curvature of an arch is on the springing line, and when the radius of curvature is equal to one-half the span, the arch becomes a common **circular arch**, as is illustrated in Figs. 3 and 9. In Fig. 3, the arch ring is of equal depth all around and the voussoirs are all of the same size; the dressing is rock-faced with pitched joints. Sometimes the voussoirs have a margin draft, as shown at *b* and *c*.

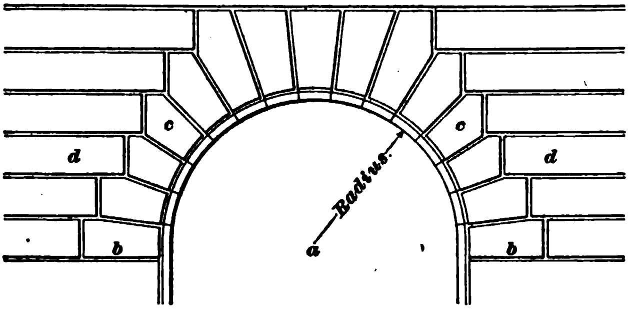

Fig. 9

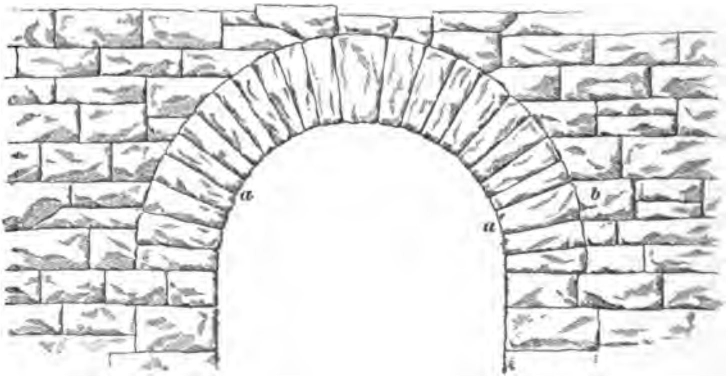

Fig. 10

16. Arches that are used in coursed ashlar are often built as shown in Fig. 9. In this figure, *a* is the center of curvature of the arch; from *b* to *b* is the springing line; *c*, *c* are the ring stones; and *d*, *d*, the coursed stonework. Arches of this description are more expensive to construct than those in which the intrados and extrados are concentric, on account of the greater number of patterns required, the increased quantity of rough stone needed, and the work necessary to properly dress the voussoirs.

17. **Rubble Arches.**—For rough work, arches are sometimes built of **rubble,** as shown in Fig. 10, in which *b* represents the wall carried by the rubble arch, the ring stones *a* of which should be narrow and roughly dressed to a wedge shape. Such arches should always be laid in cement mortar, as they depend considerably on the adhesive power of the mortar for their stability.

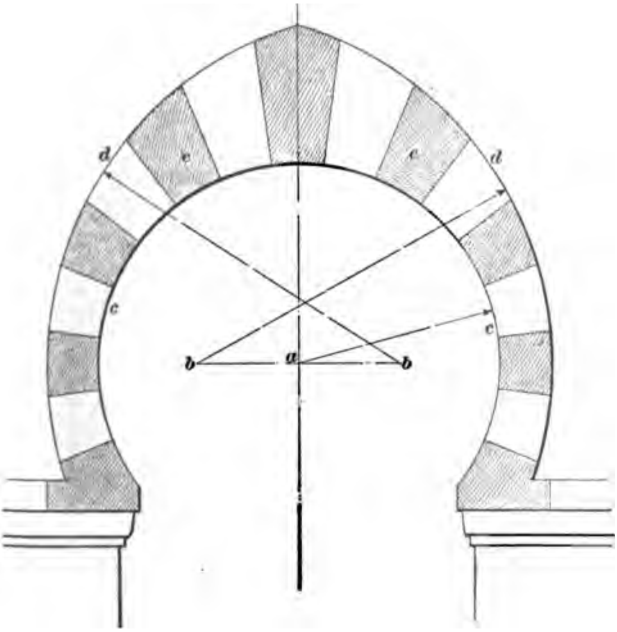

FIG. 11

18. **Moorish Arches.**—If the center of curvature is raised above the springing line, as shown in Fig. 11, the arch is then called a **horseshoe, or Moorish, arch.** The

Alhambra, at Granada, Spain, has some of the best examples of this arch. Sometimes, the Moorish arch is built with the intrados and extrados concentric, and often with the intrados having a horseshoe form and the extrados a pointed form. The example given shows the latter method of construction. At *a* is shown the center for the horseshoe intrados; at *b*, *b* are the centers for the pointed extrados of the arch; *c*, *c* indicate the soffit of the horseshoe arch; *d*, *d*, the upper side of the arch ring; and *e*, *e*, the voussoirs.

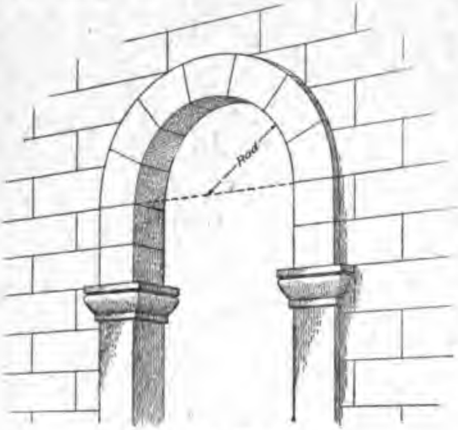

FIG. 12

19. Stilted Arches.—If the portion of an arch below the center of curvature is made vertical, as shown in Fig. 12, instead of curving in again, as in the Moorish arch, the arch is said to be **stilted.** This style of arch is often used where two or more are to be placed adjacent to each other. The *stilts* are unable to take any horizontal thrust, and the arch must therefore be properly supported on the sides at a level with its center of curvature. Many forms of arches may be made stilted as, for instance, the *lancet arch*, which will be described later.

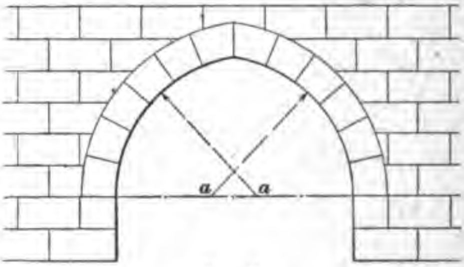

FIG. 13

20. Two-Centered Arches.—Instead of turning the entire intrados from one center, two centers may be used.

This forms an arch known as the **two-centered arch,** an illustration of which is given in Fig. 13. The sides are formed by circular arcs drawn from the centers *a*, *a* with the same radius. This method makes a point in the crown of the arch, for which reason it is sometimes called a *pointed arch.*

21. Venetian-Gothic Arches. Fig. 14 shows an arch having the intrados semicircular and the extrados pointed. Such arches are found in Venice, and are sometimes termed **Venetian-Gothic arches.** At *a* is the center for the semicircular intrados; at *b*, *b* are the centers for the extrados, or pointed arch, and *c c* is the springing line.

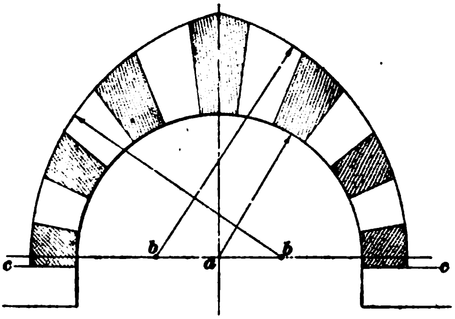

FIG. 14

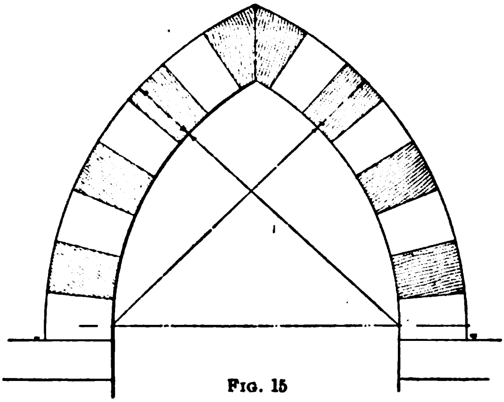

FIG. 15

It will be noticed that the more closely the points *b*, *b* approach each other, the less pointed is the arch, and that when these two points become one, as at the point *a*, the arch is a common circular arch. Conversely, as the two centers of curvature separate, the arch becomes more and more pointed.

22. Equilateral Arches.—Fig. 15 represents a pointed arch known as an **equilateral arch.** In an arch of this character, the center of curvature of one intrados is on the curve of the other intrados, and the extrados are concentric with their respective intrados.

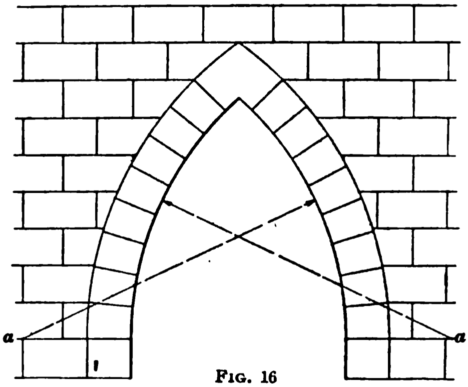

FIG. 16

23. Lancet Arches.—The centers of curvature of a two-centered arch may be placed at a still greater distance apart than in the equilateral arch shown in Fig. 15. In Fig. 16 is shown an arch in which these

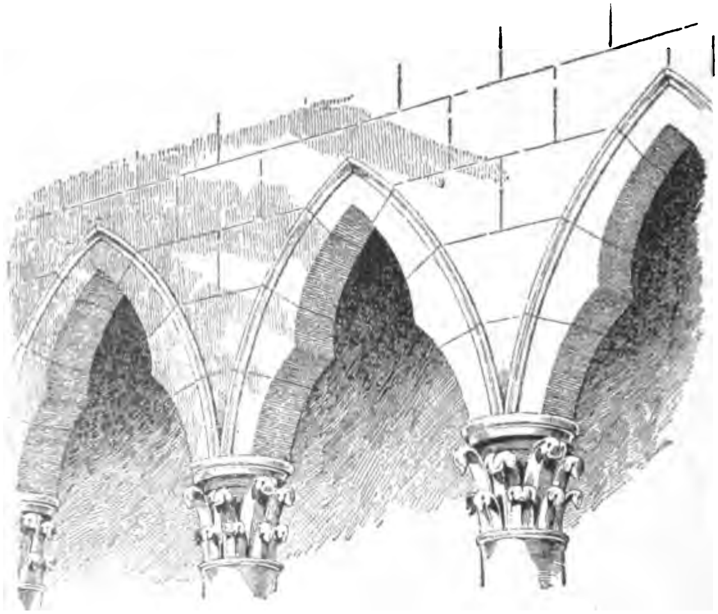

FIG. 17

centers *a*, *a* are placed very far apart. This arch is also known as **lancet arch.** These two-centered arches, together with the *two-cusped arch*, about to be described, and the *Tudor arch*, are much used in Gothic architecture.

24. Two-Cusped Arches.—The **two-cusped arch** shown in Fig. 17 is really a variety of two-centered arch. The extrados are made like the extrados of a lancet arch, but the intrados are the combination of a circular arch and a two-centered arch. There are so many styles of this arch that it is impossible to lay down rules giving any definite proportions between the parts.

25. Three-Centered Arches.—Arches having an elliptic, or oval, form are often used in architectural work. These may be formed either of true elliptic curves, or approximately of three or more centered circular arcs. Very flat elliptic arches are not suitable for any considerable span, and, if built, should have large piers or abutments; or, beams may be placed above the arch to relieve it of some of the load.

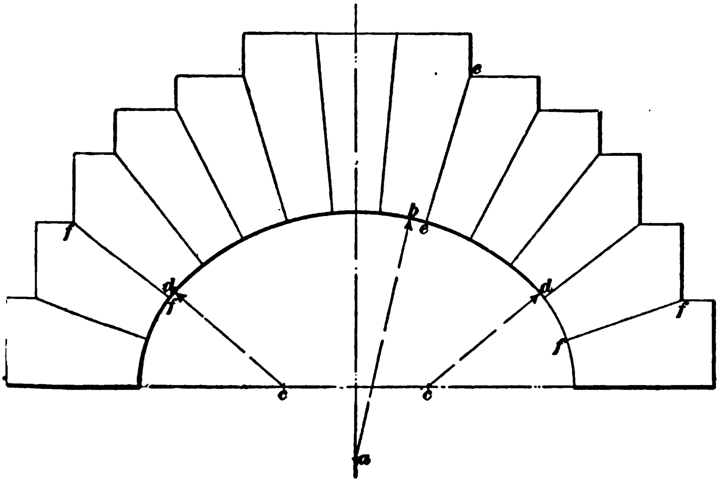

Fig. 18

The method of finding the direction of the joints in a **three-centered, or false, elliptic arch** is shown in Fig. 18.

The radius for the middle of the arch is *a b*; the radii for the two haunches are the lines *c d*. The joints of the voussoirs in the central portion are drawn with *a* as a center, as at *e e*, etc.; and the joints for the haunches are drawn with *c*, *c* as centers, as at *f f*, etc. The distance between joints is merely a matter to be decided by the taste of the architect.

26. A method of finding the voussoir joints in a **true elliptical arch** is given in Fig. 19.

Find the foci of the ellipse by striking arcs from *c* with *a b* as a radius, cutting the major axis at *d* and *d'*. Let *e* be the point where the direction of the joint is to be found. Draw *d e* and *d'e*, and bisect the angle *d e d'*, as at *e f*; then, *e f* is the direction of the joint at *e*.

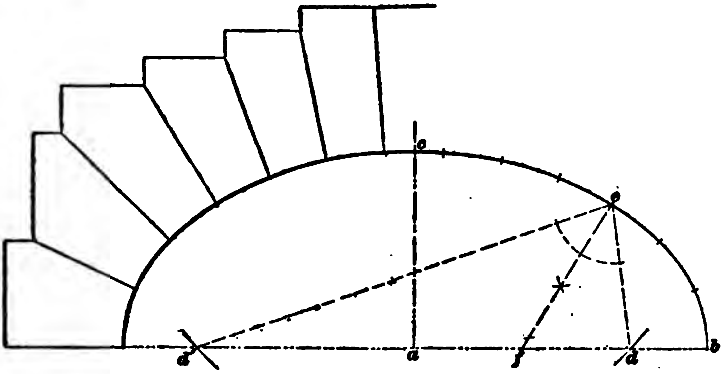

FIG. 19

27. **Four-Centered Arches.**—Fig. 20 shows an example of a **four-centered arch**, also often called a **Tudor arch.** In the illustration the span *a b* is divided into six equal parts, as at *c*, *d*, etc. To find the centers for the longer radii, with *c* and *e* as centers and a radius *c e*, describe arcs intersecting at *f*; draw *f c* and *f e*, and produce these lines to *g*, *h*, *i*, and *j*. The last two points will be the required centers for the middle part of the arch. With *c* and *e* as centers and a radius *c a*, describe arcs *a g* and *b h*; with *i* and *j* as centers and a radius *i h*, describe the arcs *h k* and *g k*.

28. In Fig. 21 is shown an arch similar in construction to Fig. 20, but the span *a b* is divided into only four equal parts. The distances *a c* and *b d* are each made equal to *a b*; lines are then drawn from *c* through *e*, and produced to *g*, and from *d* through *f* and produced to *h*. The arcs are then struck from *c* and *d* for the upper portion, and from *f* and *e* for the lower portion.

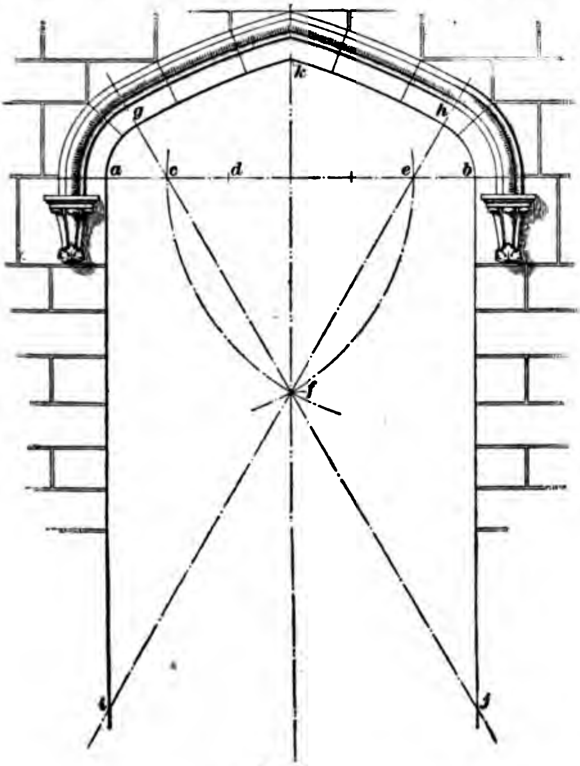

FIG. 20

29. Ogee Arches.—Fig. 22 shows a four-centered arch with a reverse curve at the apex, and it is sometimes called an **ogee arch.** This arch is usually, although not necessarily, made stilted, the stilt being about one-seventh of its total height.

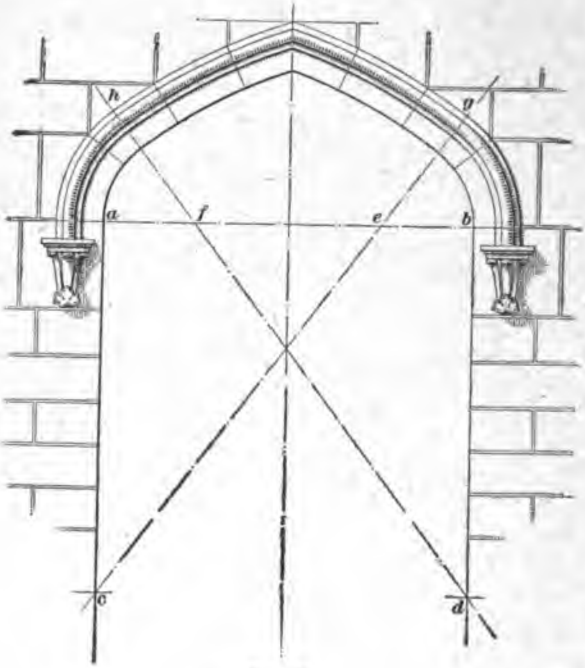

FIG. 21

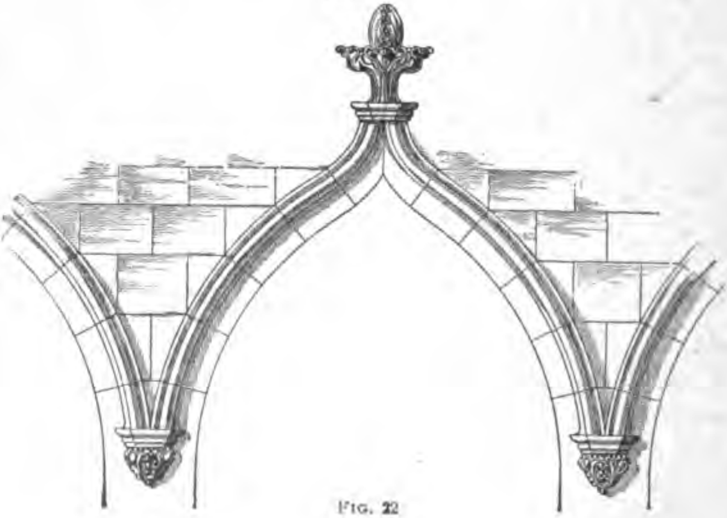

FIG. 22

30. Rampant Arches.—Fig. 23 shows a **rampant arch.** Such an arch is used in a flying buttress, as in the illustration, or to support a flight of stairs. To construct a rampant arch, draw the base line *a b* equal to the horizontal length of the span. At *a*, lay off the desired angle of

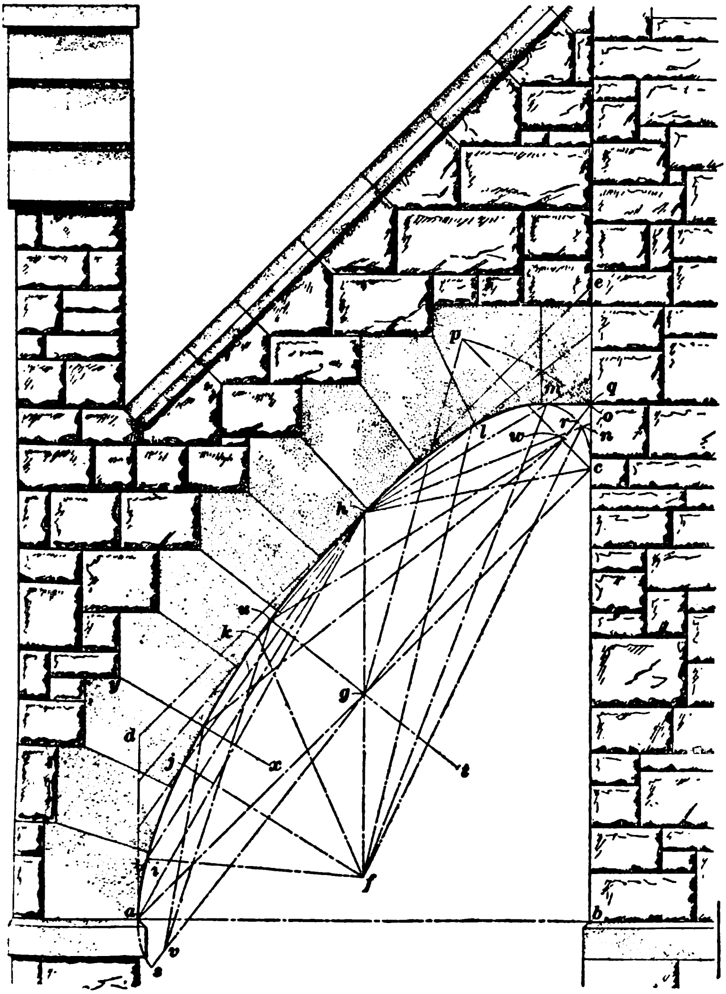

FIG. 23

inclination of the arch *bac*. Draw a vertical line *bc*, intersecting the line *ac* at the point *c*. Bisect *ac* at *g*; then, *ag* equals *gc*. At the points *a*, *c*, and *g* draw lines perpendicular to *ab*, as *ad*, *ce*, and *fgh*. The latter perpendicular *gh* is made equal to the amount of rise it is proposed to give to the arch, and *fg* is made equal to *gh*. Now, through *h*, draw the line *de* parallel to *ac*. Divide the line *ac* into any even number of equal parts, and divide *ad* and *ce* each into one-half as many equal parts. From *h*, draw lines to the points on *ad* and *ce* just found. From *f*, draw lines through the points on the line *ac*, producing them to intersect these first drawn, as at *i*, *j*, *k*, *l*, *m*, and *n*. These points, together with the points *a*, *h*, and *c*, lie on the required curve of the intrados. Usually, the descending part of the curve at the right-hand side of the arch, namely, the part *mnc*, is omitted, as it is liable to be a source of weakness.

There are two ways of finishing the soffit, if the part of the curve just mentioned is considered undesirable. The arch may be designed slightly larger, so that the actual arch will meet the wall at its highest point *m*; or, from this point *m*, a horizontal line *mo* may be drawn to the wall to complete the curve. The latter method has been followed in the illustration.

31. The curve found for the intrados is an ellipse. To locate the axes and foci of the ellipse, erect *cp* perpendicular to *ac* at *c*, and make it equal in length to *gh*. With *g* as a center and with a radius *gp*, describe an arc, intersecting *ec* at *q*. A line drawn from *q* through *g* will give *rs* as the major axis, and *tu* perpendicular to it at *g*, will be the minor axis. Taking the distance *gr* as the radius and with *u* as a center, describe arcs cutting the major axis at *v* and *w*. These points will be the foci of the ellipse, and the joints between the stones may be found, as at *xy*, by the method previously described.

CONSTRUCTION OF ARCHES

32. **Voussoirs.**—The ring of an arch should be built of the very best kind of ashlar masonry, cut so that the voussoirs bear evenly and closely against one another with the thinnest possible joints, as it is desirable to have very little mortar between the stones. The width of the ring stones is seldom less than 1 foot or more than 2 feet, and the thickness (back into the wall) varies from 1 to 3 feet. The joints of the stonework should be of the same width throughout the arch, so that the bearing may be uniform over the entire surface. The thickness of the joints depends somewhat on the character of the finish. If the work is finely dressed, $\frac{3}{16}$ inch is the usual thickness; while in rock-faced work it is seldom made less than $\frac{3}{8}$ inch; $\frac{1}{4}$ inch is all that is usually allowed for the best work.

33. Usually, the arch is divided into an odd number of voussoirs, and the keystone is placed in position last. Except for the convenience of the masons in laying, and for the sake of appearance, there seems to be no special reason for an uneven number of voussoirs, and some authorities claim that an even number makes a better job. Narrow voussoirs, while more economical in the amount of material used, are more expensive in labor, as more cutting and fitting is required than with wider ones.

Sometimes, two of the voussoirs are cut from one stone with a false joint between. Although this is generally done for economy, there are cases when the stability of the arch is thereby increased; as, for example, when the skewbacks are made twice the size of the remaining voussoirs, the number of joints is decreased, thus tending to strengthen the arch.

34. **Backing.**—As a rule, cut-stone arches in buildings are only from 6 to 8 inches thick, having a backing of a less costly kind of stonework. Large arches, especially when both sides are visible, as in some entrances, porches, etc., are often constructed as shown in Fig. 26. In this case, the

stone ashlar is backed with brick, and tied together with clamps, as indicated at *f*.

35. Beams and Tie-Rods.—When an arch is to be built in a position where abutments of sufficient strength to resist the arch thrust cannot be provided, as, for instance, in a circular tower or near the corner of a building, one or more steel beams should be laid on the wall immediately over the arch, with the ends resting on the masonry forming the abutments. Anchor rods securely embedded should be used to tie together the beams and the stonework. A thin crack should be left without mortar under the central portion of the beams, so that if they deflect under the load, they will not rest on the arch. By this method, the abutments are relieved of the arch thrust due to the load, which is, instead, transmitted vertically to the supports.

In building a segmental arch, it is a good precaution, if conditions permit, to tie the ends of the arch together with steel rods so as to take up the thrust until the mortar in the masonry has thoroughly set.

36. Bonding.—Whenever arches are carried on piers or columns, care should be taken in cutting the springing stones, so that they will bond properly into the spandrel masonry. In Fig. 24 is shown two arches springing from a pier; if the stones *a, a* are so cut that the wedge-shaped piece *b* is necessary to fill up the space between them, there

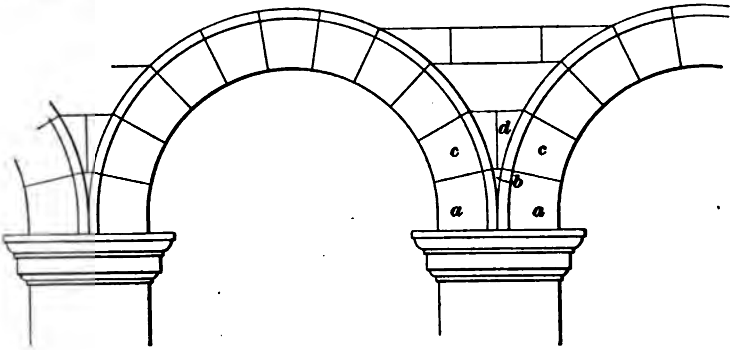

FIG. 24

is danger that the weight of masonry over *b* will force it down, and displace the springing stones *a*, *a*. To prevent this, the stones *a*, *a* should be of one piece, and those marked *c*, *c* should be cut so as to make a vertical joint at *d*, and thus avoid using the wedge-shaped piece between these two ring stones.

A somewhat similar case is represented in Fig. 25. Here, the back of the arch extends almost to the corner of the wall, as shown at *b*. Should the brick wall rest on such a small footing, it would evidently tend to separate from the arch, through some of the lower bricks being thrust out of place. The springing stone *a* should, therefore, be made to extend clear through the wall to the face, and the brick should rest on the part *b*, as shown at *c d*.

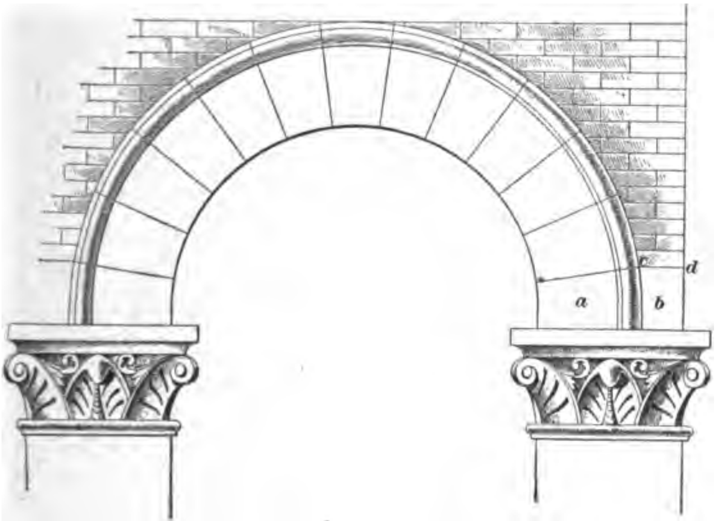

FIG. 25

37. Moldings.—Arches are often decorated with more or less elaborately dressed stone, known as **label** and **soffit moldings**. The former is sometimes cut in the ring stones, but more often forms a separate course of thin stone. If such is the case, the stability of the arch should not depend on the strength of the stone in the molding.

The soffit molding is frequently in the form of a bead and cove, or three-quarter round and cove, or some similar shape. Entrance arches are often decorated with various devices cut in the soffits, especially in entrances to cathedrals, public and office buildings, etc.

In Fig. 26 the label mold is shown at *a*; the arch rings, at *b* and *e*; the soffit mold, at *c*, *c*; the brick backing, or filling, at *d*; and the voussoir joints, at *g*. Every alternate pair of voussoirs should be tied together with galvanized-iron clamps, doweled into the stones, as shown at *f*.

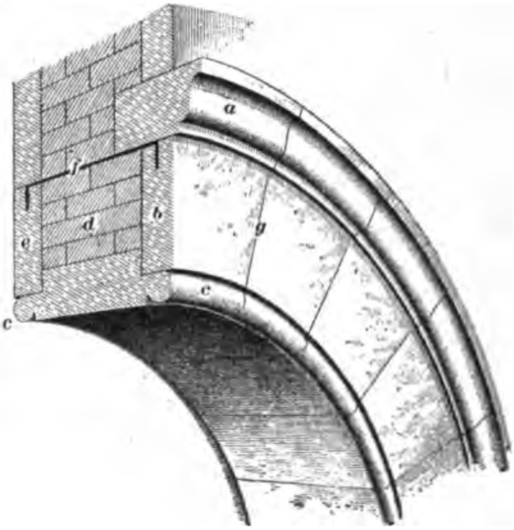

FIG. 26

38. Centers.—In building an arch, it is carried up from both piers, or abutments, at the same time. During construction, the stones must be supported until the ring is completed. For this purpose, a framework made of planks having one side cut to exactly fit the curve of the arch is used. This framing, known as a **center**, is supported on posts, and the usual method is to insert wedges between the center framing and the posts supporting it, which, when the arch has been completed and the mortar has set, are driven out gradually, so as to bring the load on the arch ring without shock. The center should be strong enough to support the weight of the arch and a portion of the wall above, as no weight should be put on the arch until the mortar in the joints has become hard.

39. Fig. 27 represents a form of center suitable for arches of small span. At *a*, *a* are shown the bearers, which are cut out of 2-inch plank and to a radius about 1 inch less

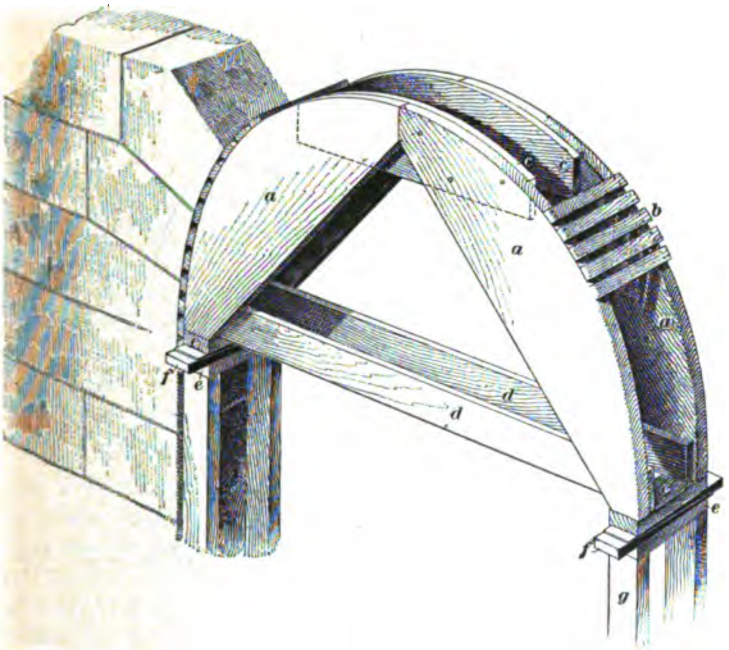

FIG. 27

than that of the intrados of the arch. At *c*, *c* are indicated pieces of plank, nailed at the crown of the center to splice and stiffen it. Small bearing strips *b* about 1 in. × 2 in. in section are nailed to the curved pieces *a*. At *d*, *d* are shown the longitudinal braces; at *e*, *e*, the plates under the center and on top of the posts; at *f*, *f*, the wedges; and at *g*, the posts, which, if quite long, should be braced at the middle with struts.

40. For arches of considerable span, centers more strongly built are necessary. Fig. 28 shows a good form of construction. At *a*, *a* and *b*, *b* are represented the bearers,

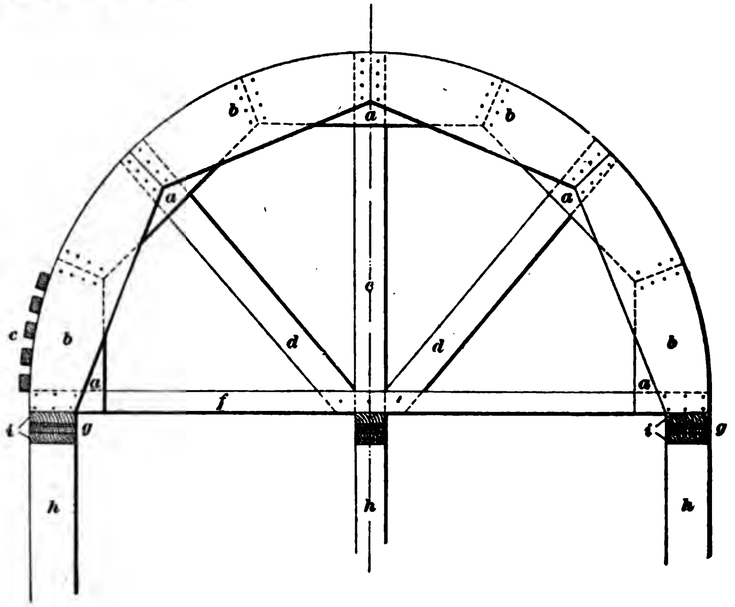

FIG. 28

breaking joint as shown; *c* indicates the bearing strips; *e*, the upright; *d*, *d*, the inclined braces; *f*, the tie-piece; *i*, *i*, the bearing plates, with wedges *g*, *g* between; and *h*, *h*, the side and center posts.

CARPENTRY

(PART 1)

TIMBER AND ITS USES

SELECTION OF TIMBER

1. The selection of timber and lumber depends largely on the character and grade of material carried in stock by local dealers; nevertheless, a knowledge of the best kinds of wood for special purposes will be very useful, especially when important work is to be undertaken and the best results are desired. Light framing material is usually selected from woods that are plentiful and cheap, while heavy framing should be formed, where practicable, from timber possessing both strength and durability in the highest degree.

As the exterior trim of buildings is subjected to the extremes of hot and cold weather, and to wind and rainstorms, a durable material that can be easily worked and is least influenced by these changes should be selected. The fibers should be firm and elastic, without being brittle, and of sufficient toughness to avoid splitting when being nailed in place, and to avoid warping and checking after being erected. Where wood is embedded in concrete or is buried whole or in part in the ground, the first consideration is that of durability. For floors subjected to heavy work, the wearing quality is the first consideration. When interior finish is to be painted, any sound material that will hold glue and stand well may be used; but where the wood is to be finished in its natural color, by varnishing or by waxing, its color and texture will usually govern the selection.

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2. Wood for Special Purposes.—The following list will serve as a guide in selecting and specifying the different kinds of wood for special requirements, the material being stated in the order of its durability.

Light Framework: Posts, beams, sills, studs, plates, joists, roof framing, etc.; the various kinds of pine, spruce, and Eastern and Western hemlock.

Heavy Framework: Posts, girders, floorbeams, braced framing for roof trusses, etc., such as are used in mill construction; oak, long-leaf or Georgia pine, Douglas fir or Oregon pine, white pine, spruce, and hemlock.

Long Timbers and Flagpoles: Long-leaf pine, Douglas fir, and spruce.

Exterior Trim: White pine, Douglas fir, redwood, red and white cedar, and cypress; the last-named wood cannot be recommended for good work on account of its layers rising through exposure or painting.

Shingles: White pine (particularly when split and shaved), redwood, cypress, Western red cedar, Southern white cedar, and spruce.

Siding: White pine, redwood, red and white cedar, cypress, Douglas fir, and spruce.

Posts and Sleepers in Concrete or in the Ground: Locust, chestnut, cypress, redwood, Douglas fir, and red and white cedar.

Piles and Cribbage: Oak, elm, long-leaf pine, black spruce, Douglas fir, cypress, white spruce, and white pine; in salt water, use only the first four named.

Solid Framed Doors, Sash, Wainscoting, Etc.: Old-growth clear white pine, Douglas fir, redwood, cypress, short-leaf or Carolina pine, and poplar (the latter for doors and wainscoting only).

Veneered Work: The inner layers, or *cores*, are usually made of white pine or chestnut—two kinds of wood that hold glue very well. The surface veneers of the various kinds of hardwood are usually $\frac{1}{8}$, $\frac{3}{16}$, and $\frac{1}{4}$ inch in thickness; but for "figured" mahogany and the more expensive woods, the veneers are cut as thin as thirty to the inch. Owing to the increased cost of clear white pine, this material is also being used extensively for veneers, and the scraps that formerly were used as fire-wood, are now utilized in building up cores for veneered work.

Flooring: Quarter-sawed maple, white oak, and Georgia pine, for heavy service, such as in stores, offices, and factories, and white pine, Douglas fir, cypress, spruce, short-leaf pine, and hemlock for dwellings.

Parquet flooring, or flooring laid in short strips, forming geometric patterns, is usually composed of mahogany, oak, cherry, birch, or maple.

Linen Closets: Fragrant red cedar from Alabama or Florida.

Interior Trim: White pine, long-leaf pine, Douglas fir, redwood, cypress, spruce, short-leaf pine, and poplar. All the hardwoods are used for high-grade interior work, but all framing and paneling should be veneered; for durable work, the material must be properly kiln-dried, and should not be installed in the building until the plastering is thoroughly dry.

Furniture: Mahogany, rosewood, walnut, ebony, oak, cherry, birch, maple, beach, redwood, cedar, pine, and basswood. The rarer woods are usually employed in inlaid work, called *marquetry*.

Counter and Table Tops: Birch, cherry, and teak are excellent materials for the tops of tables and counters, especially those used in restaurants, pantries, and kitchens, where they are washed almost constantly. Although mahogany is largely used for this purpose, it will be found that water will render it spongy and absorbent, and the color will soon be reduced to a dull, grayish brown.

DECAY AND PRESERVATION OF TIMBER

3. Decay of Timber.—If sound timber is placed in a dry, well-ventilated position, or is entirely submerged in water, it should last for centuries. Old age is evident when the wood becomes weak and brittle. Decay, or rot, may be caused by the presence of sap, conditions that tend to the germination and attacks of fungi, and alternate wetting and drying of the material.. Damp earth, damp walls, and contact with mortar hasten decomposition, and warm, humid air and lack of ventilation are also causes of decay. Timber cut from trees that have lost their vigorous growth either by disease or by old age is weak, brittle, and perishable. The decay in this case works up from the roots and forms rotten heart wood.

4. **Dry Rot.**—The disease of timber known as **dry rot** is caused by confining timber in a position where there is no circulation of air, which promotes a growth of fungus that eats into the fibers and reduces them to a powder. The fungus first appears like a frost, and then spreads in fine thread-like lace over the surface, eventually forming a vegetable-like growth with spreading leaves.

Dry rot occurs in joists and floors over warm, unventilated portions of cellars; in unseasoned beams and joists built solidly into walls; in heels of trusses incased in box cast-iron shoes which prevent sap from escaping; in floor joists and sleepers embedded in mortar; in wall plugs driven into damp walls; in flooring covered by impervious material, such as oilcloth, linoleum, rubber tiles, etc., which prevent the access of air and retain dampness.

Charring, tarring, and painting unseasoned timber also cause dry rot.

5. **Wet Rot.**—The condition called **wet rot** may occur in growing timber, being caused by rain entering it through cleavages and wounds in the tree; in piled timber, due to too long exposure outdoors and not being under cover; and in framework, posts, piles, and exterior woodwork subjected to alternate dampness and dryness. Exterior woodwork should be well air-seasoned before being erected, all joints and ledges being so formed as to prevent the lodgment of moisture, and then protected by painting. Flushing porch floors with a hose rots them more quickly than does the action of rain, as in the former case a great deal of the water is forced into the joints of the floor. The

woodwork in kitchens, laundries, and other places where much scrubbing is done soon succumbs to wet rot. As wet rot spreads and attacks the sound timber, the diseased portions should be cut out in all work where durability is required.

6. **Methods of Preserving Timber.**—In general, building-construction timber can be preserved for an indefinite time by giving attention to a few simple requirements. It is well to remember that timber requires plenty of pure, fresh air, which suggests that the spaces it occupies should be well ventilated; also, it should be kept as dry as possible, and where exposed, it should have a coating that is impervious to moisture.

Enduring Work.—For enduring work the timbers should be thoroughly seasoned before being put in place. Thus, the sap will be evaporated, all valuable gums in the wood, by hardening, will become fixed, and fermentation is not likely to occur.

Joists Built Into Walls.—Air spaces should be left around all beams and joists built into walls. A good plan is to insert slates on each side of the timber as the walls are built, pulling them out before the brickwork or masonry is corbeled over the spaces.

Posts in cellars should rest on stone or metal bases, at least 3 inches above the finished floor level.

Basement Partitions.—If made of wood, basement partitions should rest on brick dwarf walls, at least three courses above the floor level.

Basement Floors.—Spaces under wooden basement floors should be well ventilated, and where the soil is of a clayey nature and retains moisture, the surface should be covered with cement concrete and finished with a coating of hot liquid asphalt. This precaution is also necessary for footing courses of masonry where moisture is apt to rise up into the brick and stone walls by capillary attraction and thus affect the woodwork.

Posts Set in the Ground.—Posts that are to be set in the ground should be made of well-seasoned material, and should either be charred by burning or be coated with coal tar. They should always be set in the ground *butt up;* that is, in a direction opposite to that in which the tree grew. By following this plan, it has been found that moisture from the earth does not ascend so readily. The sap valves in the wood open upwards from the root, and when thus reversed they prevent the moisture from ascending.

Floors Subject to Washing.—Floors that receive much washing, especially porch floors, should have the matched joints well coated with white- or red-lead paint.

Woodwork Adjacent to Stonework or Brickwork.—Door and window frames, wainscoting, and trim adjacent to stone and brick walls should also be well coated with paint similar to that just mentioned.

Porch Posts.—Posts for porches should not be placed in direct contact with the floors, as rainwater and water used for cleaning ascends the pores of the wood and causes decay. Several devices are used to isolate posts from floors.

Outside Trim.—The trim used on the outside of buildings should be well seasoned. All joints should be carefully made, so as to prevent the lodgment of water; they should also be well painted before being put together. After the priming coat, all shakes and cracks should be filled with white lead and oil putty, and the entire woodwork should then be properly painted—repainting at least every 3 years.

Gutters and conductors should be regularly examined for leaks. When gutters are placed on the roof or are sunk in the cornice, much damage may be done to the roof before any defects are noticed. Where practicable, gutters should be so placed that obstructions, overflows, and leaks will do as little damage to the woodwork as possible.

7. "Bleeding" Timber.—"Bleeding" pine trees for their resin—to which only the long-leaf and Cuban pine are subjected—has generally been regarded as injurious to the timber. Both durability and strength, it was claimed, were impaired by this process, and in the specifications of many architects and large consumers, such as railway companies, "bled" or "boxed" timber was excluded.

Since the production of resin is one of the leading industries of the South, and since the process affects several millions of dollars' worth of timber every year, a special investigation—involving mechanical tests and physical and chemical analyses of the wood of bled and unbled trees from the same locality—was carried out by the Division of Forestry, United States Department of Agriculture. The results of the tests prove conclusively (1) that bled timber is as strong as unbled if of the same weight; (2) that the weight and shrinkage of the wood is not affected by bleeding; (3) that bled trees contain practically neither more nor less resin than unbled trees, the loss of resin referring only to the sap wood, and, therefore, the durability is not affected by the bleeding process.

Table I shows the remarkable numerical similarity between the average results for three groups of trees, the higher values of the bled material being readily explained by the difference in weight.

TABLE I

RESULT OF TESTING BLED TIMBER

Long-Leaf Pine	Number of Tests	Weight of Test Pieces Pound per Cu. Ft.	Bending Strength Pounds per Square Inch	Compression Strength Pounds per Square Inch
Unboxed trees . . .	400	.46¼	12,358	7,166
Boxed and recently abandoned . . .	390	.49⅜	12,961	7,813
Boxed and abandoned 5 years . .	535	.47½	12,586	7,575

The amount of resin in the wood varies greatly, and trees growing side by side differ within very wide limits. Sap wood contains but little resin (1 to 4 per cent.), even in those trees in which the heart wood contains an abundance. In the heart wood, the resin forms from 5 to 24 per cent. of the dry weight (of which about one-sixth is turpentine), and cannot be removed by bleeding, so that its quantity remains unaffected by the process.

Bled timber, then, is as useful for all purposes as unbled, for it is seen from the foregoing that bleeding does not impair the strength of timber; neither is its durability materially affected. These tests settle this often disputed point conclusively, and it needs no further discussion.

STRUCTURE AND GROWTH

8. General Remarks.—A general knowledge of the properties and kinds of timber, the laws of growth and development, the characteristics of good timber, its natural defects, its conversion into building material, its shrinkage during the process of drying, modes of drying, etc. is very important in order to judge intelligently the value of the material and to provide for its disposition and arrangement so as to secure the most stable and permanent construction.

9. To suit the purposes of the carpenter and joiner, the tree should not be cut until it has reached the period of mature growth; soon after this growth is reached, the heart begins to decay, hence the necessity of cutting, or *felling*, as it is called, at the proper time. After felling, the trunk and the larger branches are cut into suitable lengths, in which condition it is classified as *timber*, but when cut up into planks, etc. it is generally called *lumber*.

10. Divisions of Trees.—There are three divisions of trees, each being classified in accordance with its respective mode of growth: (1) The *exogenous*, or outward growers, in which the stem increases by the formation of annual layers deposited around the *outside* of the preceding layer; such as oak, chestnut, pine, hemlock, etc. (2) The *endogenous*, or inward growers, in which the woody matter is formed on the *inside* of the stem, of which the palmetto tree is an example. (3) The *acrogenous*, or summit growers, in which the stem is produced by the lower stalks of the leaves growing together, such as tree ferns.

11. Exogenous Growths.—The first division, or the **exogenous method** of development, is the one that furnishes the timber for the wood worker. By examining the section of a young oak tree, such as shown in Fig. 1, which is a microscopic enlargement of a section of a stem having 3 years' growth, it is found to have three well-defined kinds of tissue: the pith, the woody layers, and the bark. At the core, or heart, at *a*, is seen the *medulla*, or pith, which is composed of cellular tissue—a net-like fabric of cells, resembling a honeycomb; at *b*, the *medullary sheath* surrounds the pith and is composed of spiral vessels and fiber ducts for the conveyance of the sap; this constitutes the inner layer of the first year's growth. At *c* are the *wood cells*, or fiber tubes, composing the successive annual layers, which are formed in a series of concentric rings; each annual layer, as shown at *1*, *2*, and *3*, is called a *zone*, or circular belt.

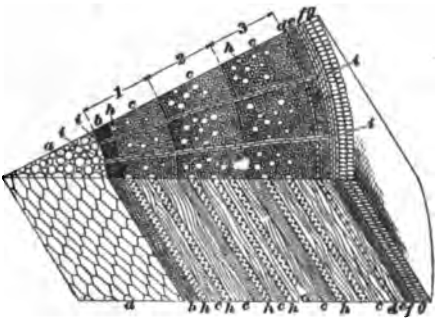

FIG. 1

12. Observe that there is a well-defined line of separation between each pair of zones. About one-half of the width of the zone is occupied by bundles of fiber tubes containing large sap vessels *h*, *h*, whose walls are pitted and dotted as shown (this portion represents the spring growth), while the remainder of the width is filled with fiber tubes of much closer texture (this portion represents the summer growth). In ash, chestnut, and oak, the vessels *h*, *h* are easily observed.

The line of separation is caused by the suspension of the growth of the stem during winter. When the tree is young, the tissue is open and spongy and filled with various fluids, but in process of time, it becomes thickened and firm and the ducts close, the thickening of the tissue commencing with the layer first formed. For this reason, the best timber is secured from mature trees, as the fibers have then become compact and firm, and are less sensitive to changes of temperature when once well seasoned. Both young and second-growth timber are unfit for all purposes where strength, durability, and "staying qualities" are required, the last-named quality being a most essential one for wood used by the carpenter and the joiner.

13. **Heart Wood and Sap Wood.**—Much difference as to strength and appearance exists between the mature, compact, inner layers of the *heart wood*, called **duramen**, and the layers of the *sap wood*, called **alburnum.** In the former, the fibers are firm and dense and possess a deep rich color, while in the latter the fibers are open, porous, and filled with sap and usually have a pale color. The sap wood possesses little strength, and the sap it contains is largely composed of a sugary substance, which invites the attack of insects and hastens decay.

14. **Tree Zones.**—When zones are visible, the age of a tree may be ascertained by counting them. Frequently, however, their growth is interrupted by severe frosts and other conditions, causing a line of separation. Several lines may be formed in one year, and thus lead to an erroneous estimate. That part of the tree which is more fully exposed to the sun will be found to have wider layers than the other part; hence, the pith, or heart, is seldom in the center of the stem. Softwoods usually possess wider zones than the hardwoods, and it will be observed that much difference exists between the width of the zones in the same tree.

As in the animal kingdom there are three periods of existence, namely, infancy and youth, vigorous life, and declining vitality and decay, so also a similar series exists in the vegetable kingdom. When the tree is most vigorous, it produces the largest zones. In the oak, this occurs between the twentieth and the thirtieth year, after which its productive power is gradually lessened, and as it grows older the zones become smaller.

15. Cambium Layer.—Between the inside of the bark and the woody layers is located the **cambium layer**, as shown at *d d*, Fig. 1, which consists of a cellular tissue like the pith, but contains, in addition to the cell sap, the rich life-giving secretion called *protoplasm*, without which the tree cannot live. This layer possesses the property of building up the woody formation by the product of ever-increasing cells, and only by the vital energy of this layer, also called the *thickening zone*, can the tree increase in diameter.

16. Composition of Bark.—The bark consists of three distinct layers. The **inner, or bast, layer** *e e*, Fig. 1, is composed of woody fibers combined with a cellular tissue, which retains a flexible, rubber-like elasticity and allows it to expand as the woody layers are produced by the cambium. The **central layer** *f f* is comprised of prismatic cells and tubes filled with juices, while the **outer layer** *g g* is composed of a corky substance of cellular structure. During the growth of the tree there is a continual distending and separating of the fiber and cellular tissue composing the bark, which is renewed and strengthened by means of the cambium layer.

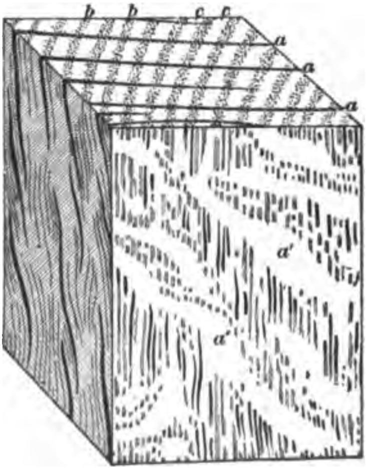

FIG. 2

17. Medullary Rays. In the stem of several trees, especially the oak and the locust, lines that radiate from the center of the tree will be observed; these are called **medullary rays.** When they connect the pith to the bark, as at *i i*, Fig. 1, they are called *primary rays;* but where they extend through only a portion of the stem they are called *secondary rays.*

These medullary rays, generally called *silver grain*, when exposed on the surface of the cut lumber, consist of a series of vertical plates, or sheets. Originally of cellular tissue, they have become flattened by compression until they resemble sheets of mica; they are not, however, continuous vertically, but are buckled and present a serpentine outline, when exposed on the edge, as shown in Fig. 2. On the end-cut in the figure, the medullary rays are marked *a*, *a*, while the porous fibers of the zones are marked *b*, *b*, and the close or denser ones are marked *c*, *c*.

The appearance of the silver grain, or medullary plate, when cut nearly parallel with its direction is shown at *a'*, *a'*; it is the presence of these medullary rays that gives so much beauty to quartered oak. The rays are prominent also in beech and sycamore, but are not so well defined in birch, chestnut, and maple.

18. Structure of the Stem.—**The structure of the stem,** as it presents itself to the observer on examining the end of an oak or an ash tree of 13 years' growth, is shown in Fig. 3, in which the porous fibers or sap vessels of the coarser texture are shown at *a*, *a*; the closer texture at *b*, *b*; the primary medullary rays at *i*, *i*, and the secondary ones at *j*, *j*; and the zone of the bark at *c*, *c*.

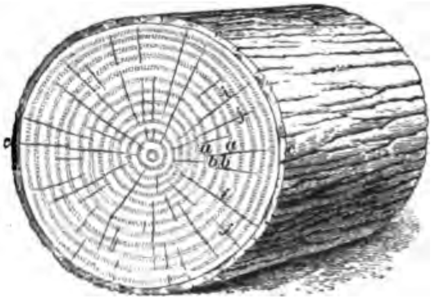

FIG. 3

In temperate climates, the process of growth may be thus described: In the spring, the roots extract the juices (generally called *crude sap*) requisite for vegetable growth from the earth; this crude sap circulates from cell to cell and through the fiber tubes, and ascends and forms the leaves. At the upper surface of the leaves, under the influence of light, chemical changes take place, the sap absorbing carbon from the air and becoming denser. After the leaves are fully developed, there is no further growth until autumn, when the so-called *elaborated sap* descends by the under side of the leaves, enters the branches and stem, and continues its descent principally between the wood and the bark, where, by the action of the cambium cells, it builds up a new woody layer or zone for that year, a portion being absorbed by the bark for its nourishment. During this period the leaves fall off, and when the sap has ceased to circulate, the growth of the tree is suspended. In tropical climates, the circulation of the sap ceases during the dry season.

19. **Proper Time for Felling Trees.**—Midsummer and midwinter in temperate climates, and the dry period in tropical climates, are considered the best seasons for felling trees; in both cases, it is the time when the sap has ceased to circulate.

For building purposes, trees should not be felled until they have attained their mature growth, as already stated; nor should they be used after the tree has exhibited signs of declining vitality. The greatest number of trees arrive at maturity between 50 and 100 years, and commence to decline after 150 or 200 years. When the top of the tree ceases to send forth its full complement of leaves in the spring and bare branches remain, making it appear "stag-headed," lack of nutritive power is clearly indicated, which is a sure sign that the tree has begun to lose its strength and vitality. The timber then loses its elasticity and firmness and gradually becomes crisp and brittle.

20. **Conditions Affecting the Quality of Timber.** Trees growing in the heart of the forest are generally straight and tall, as it is necessary for their leaves to receive sunlight and air sufficient for vitalizing the sap; the lower branches of these trees last only a few years, when they die and fall off. On the edges of the forest, however, the lower branches of the trees remain alive and active, so that timber cut from such places is knotty and cross-grained, while that cut from the inside trees is clear and straight-grained.

Where streams are available, the logs are hauled, or drawn, to them and floated to the mill. This immersion in the running stream makes the sap more soluble, and tends to make it more responsive to evaporation during the process of seasoning; but if the logs are immersed too long the fiber loses its virtue and elasticity. To save the cost of hauling the waste material, portable engines and saws are frequently set up at the place where the logs are cut.

21. Dressed Lumber.—When the lumber is reduced from the dimensions originally cut from the log, it is said to be *resawed*. After lumber is planed at the mill, it is called **dressed lumber**, and is assorted into many grades.

The regular thickness of dressed lumber is $\frac{5}{8}$, $\frac{7}{8}$, $1\frac{1}{8}$, $1\frac{3}{8}$, and $1\frac{7}{8}$ inches, the thickness of the rough sawed material being $\frac{1}{8}$ inch greater than these measurements. Where $\frac{1}{2}$-inch dressed material is required, it is usually made by resawing $1\frac{1}{4}$-inch boards.

22. Cup Shakes.—In the body of sound, healthy trees there often occur circular seams, or cracks, where the layers have become separated from one another; these cracks are said to be caused by the action of violent wind storms on the stem of the tree during the formation of the woody layers, and are called **cup shakes**. They generally occur near the base of the stem, and in some cases can be detected in the standing timber by an abnormal increase in the bulk of the stem.

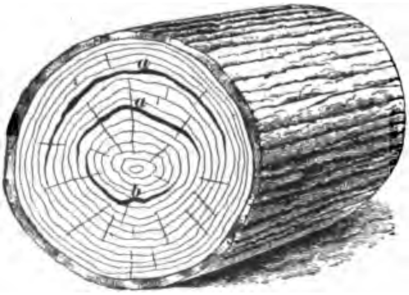

FIG. 4

Where cup shakes occur, as at *a*, *a*, Fig. 4, there is much waste in cutting the material; but where the shake is short, as at *b*, the loss is not great. Sometimes, circular bands occur in the stem, in which the wood is of a softer and more spongy character than the surrounding layers, and which, in some cases, show signs of incipient decay. This condition is assumed to be caused by the action of sharp frosts on the rising sap in the newly formed layers. When timber presents this appearance, it should be immediately rejected, as it will be short-lived and will soon decay.

23. Heart Shakes.—Heart shakes, sometimes called **star shakes,** are rifts, or cracks, which radiate from the center of the tree, as shown at *a*, *a*, Fig. 5. They are common in nearly all classes of timber, and are caused by the shrinkage of the layers, incidental to loss of vitality. After the period of maturity has been passed and decline has begun, the outer rings, being more active, derive their nutriment by absorbing the juices from the heart wood, thus causing a gradual but sure loss of its strength and virtue.

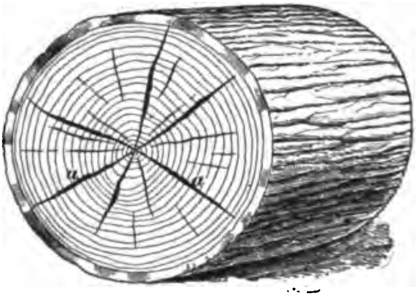

FIG. 5

24. Influence of Soil on Timber Growths.—The soil in which timber is grown exercises an important influence on its quality; where damp and marshy, the fiber is of a light, spongy character, the excess of water preventing the healthy action of the sap in forming firm and compact wood. Such soil is better adapted to the growth of light woods, as basswood, willow, and whitewood.

The hardwoods thrive best in dry, clayey soils, while those of the pine group are best developed in sandy soils.

25. Effect of Windstorms on Timber Growths. Exposure to prevalent windstorms in one direction tends to produce a twisted, spiral mode of growth. Timber of this character has practically no value for building purposes, for the reason that when cut into planks or scantlings, the fibers, running obliquely across it, give it little or no strength.

26. Various Causes of Wood Deterioration.—Trees are subject to excrescences and tumors, which lessen the value of the timber. These growths may result from the defective nature of the soil, from the attacks of animals by gnawing, or from insects that bore into the fiber.

An excess of sap in some parts of the tree shows on the outer surface by the formation of pus, or matter, which expends the virtue of the sap and decreases the value of the surrounding fiber. This disease may spread, and ultimately cause the death of the tree.

Trees are also affected by a brownish *rust*, which is caused by rainwater obtaining access to the cambium layers by means of clefts or rifts in the bark, and which, by changing the character of the sap, reduces the wood to a powder. These clefts in the bark may be the result of an unusually dry season and a rapid rising of the temperature, causing strains greater than the bark can resist; or they may be due to severe frosts, which, by acting on the sap, cause it to expand and rend the bark.

Frequently, the clefts penetrate the sap wood also, and extend into the perfect woody layers. Though these separations of the fibers may be healed up by subsequent growth, they still cause a deterioration of the wood adjacent to them.

27. There is a species of insects that deposit their eggs in the clefts of the bark, where they are hatched. These insects are a kind of beetle, and, like the moth and butterfly, pass through a larval and pupal stage of development.

The *larva*, or grub, which is hatched from this egg, immediately bores into the sap wood, which furnishes its food. The juices of the sap wood are composed of various substances—acids, albuminoids, gums, sugar, starch, oils, and water—on which the grub feeds and thrives, until it reaches its full size, when it weaves a *chrysalis*, or envelope-like sheath, and enters the *pupa* stage. This is a state of rest, in which the grub exists without nutriment while its organization is being elaborated, when it rends the envelope and emerges a perfect insect.

As the larval period extends for months, and sometimes years, during which the grub steadily eats into the fiber, it will be seen how destructive the operations of an innumerable army of these workers are, when once they get an opportunity to attack the timber. If it were not for the warfare waged on these herbivorous insects by birds, lizards, etc., which eagerly devour them, and for the action of frosts and rains, tending to prevent their excessive development, few trees would reach a state of maturity and be able to furnish sound, solid timber.

Where timber has been attacked by insects, the part affected, as well as the adjacent fiber, is rendered entirely useless for building purposes. Where the stem of a tree is regularly formed, and shows a perfect bark, free from rifts and excrescences, it will undoubtedly produce perfect timber.

28. In order to keep the timber perfect, however, the greatest care must be exercised in piling it, so as to prevent the attack of parasitic plants, called *fungi*. These constitute a lower order of plant life, which, instead of independently assimilating and digesting nourishment extracted from the soil, derive their nutriment from the organic substance of others.

The fungi are developed from *spores*, or life germs, which insinuate themselves into cracks and crevices, and propagate very rapidly. The vegetative system of these plants consists of *filiform*, or thread-like tubes, which form the roots and extract their food from the substance of the timber.

The interwoven tangle of these root hairs forms what is called the *mycelium*, which may retain the thread-like appearance of the roots, when it is defined as *filamented;* it may become so closely woven as to appear like a sheet of paper, when it is called *membranous;* or when it presents an appearance like moss, with stems and branches, in which the fibers have become firm and hard, it is called *fibrous*.

As the mycelium grows and reaches maturity it sends out thread-like shoots of closer texture than the roots, and these shoots produce the spore cases that envelope the germinal seed. The conditions that are considered favorable to the reception and germination of the spores of the fungi are warmth, moisture, the exemption of sunlight, and the presence of elements suited for their nutrition.

The substance of the timber is attacked by the mycelium either by robbing it of the valuable juices contained in its fiber ducts, reducing the texture to a dry, lifeless, sponge-like condition, or by secreting peculiar juices, which act on the woody tissue and convert it again into *cellulose* (the starchy substance of its original formation), and which is dissolved and absorbed by the parasite, thus breaking down, or decomposing, the fiber, and resulting in what is known as *decay*, or *rot*. The conditions being favorable, the work of this insidious foe continues until the entire fabric is reduced to powder. The parasite attacks the living tree as well as cut timber, and in both cases the results are the same.

29. Timber should be piled in high-and-dry locations only, and should be kept well up from the ground on staging and strips placed between the beams or boards, so as to permit a thorough circulation of air around every side of the timber. No vegetation should be allowed to grow under or around the pile, as it will create conditions favorable for the retention and germination of the spores of the fungi. The surface of the ground should be covered with ashes or gravel, which will prevent vegetable growth and also keep the surface free from moisture.

Timber deteriorates very rapidly in quality if it becomes heated, which may arise from the material being closely piled together or from being placed in a confined situation; in either case the sap is prevented from evaporating and soon begins to ferment, causing the fiber to show signs of decay. The decomposition of the fiber is also caused by alternate dampness and dryness; this is forcibly illustrated by the action on fence posts, which, although sound above and below the ground line, soon give way at the parts thus affected.

30. Wounds, caused by the branches of the trees being broken off close to their roots in the stem, often result in the rotting of the knots, as well as the surrounding fibers. This rotting is caused by the decomposition of the sap that accumulates and covers the wounds, and the *knots*, as the roots of the branches are called, assume a spongy appearance, which is called *druxy*. When the druxy knots are of a brown, fox-like color, the rot usually penetrates farther into the timber and is liable to seriously affect the healthy wood.

31. Selection of Timber.—In selecting timber for building purposes, the principal points to be carefully observed are straight grain, freedom from large or loose knots, wind and heart shakes, and the presence of the characteristics that indicate any of the diseases and imperfections of the fiber previously described. When cut, the sawdust should not be clammy or doughlike, but granular, or meallike, crisp, sparkling, and free from stringy fibers. The surface of the sawed material should be clean and lustrous, presenting a firm and bright appearance, and free from spongy or wooly fibers, which indicate lack of vitality. The heart wood should be sound and mature, and the sap wood, or layers next to the bark, should be entirely removed. The wood should appear uniform in texture, and when cut should smell sweet; a disagreeable smell is a sign of decay. When the wood is planed, it should have a silky, shining surface; the shavings should come off like ribbons and stand twisting around the fingers. When the surface appears dull and chalky and the shavings are brittle and short, it may be considered that the stock lacks much of the virtue it should possess. Good material should be uniform in color; when blotchy or discolored, it signifies a diseased condition, which may be due to defective development, or be caused by piling the lumber close together after it has been sawed. The black-and-blue streaks and patches, which often occur in lumber, are the result of close piling, which causes the sap to sour, or ferment. The defective pieces should be cut out, and only those portions which appear sound and perfect should be used in work where strength and durability are essential requirements.

LAYING OUT AND SAWING TIMBER

32. Laying Out Timber.—In converting timber into such sizes as are required for constructive purposes, there are several conditions governing the operation, which, if not understood, or if ignored, result in a loss of material, as well as affect the future conduct of the several pieces cut from the log.

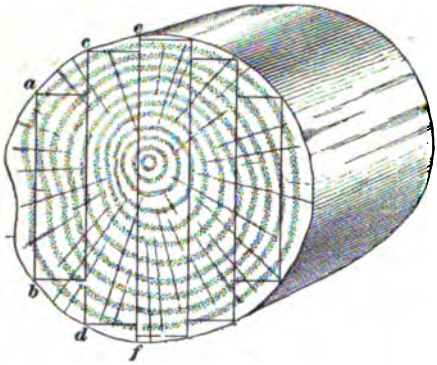

FIG. 6

The carpenter is seldom required to use timber in the round form given to it by nature, unless, perhaps, in the construction of rough and rustic work. Round timbers are also used in constructing pile foundations, and for props and supports when shoring buildings—the term *shoring* signifying a temporary disposition of timbers to afford support and rigidity to any mass or structure, but, specifically, where alterations of original conditions are being effected. They are also used for scaffolding purposes, in which both the vertical and the horizontal portions are lashed together by means of ropes.

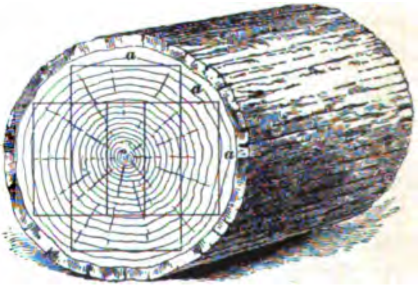

FIG. 7

Where stock of variable widths, but of equal thickness, is desired, the log would be converted into planks, as shown in Fig. 6, by a series of saw cuts, as *a b*, *c d*, *e f*, etc., parallel with each other, the edges of the planks being afterwards squared by cutting off the *waney*, or beveled portions, which formed the curved surface of the tree.

Where a large number of planks of uniform width is required, the end of the log would be marked as shown in Fig. 7, and the cuts made on the lines indicated. The portions *a*, *a*, called slabs, are usually waste material, although sometimes they are used for building fences and for siding on rustic cottages, etc.

33. The manner in which the annual rings of growth are disposed on the end section of the plank has a great influence on its behavior after it is cut from the log. During the process of *seasoning* the lumber, or the drying and hardening of its fibers by the evaporation of the natural sap, there is an ever-prevalent tendency for the boards or planks to curl and warp. This is particularly true if the process is too rapidly enforced and special care is not taken to pile the material so as to allow free circulation of air, and at the same time have it stacked so that its weight will help to keep the boards flat.

34. The cause of this tendency to curl will be understood by referring to Fig. 8, in which is shown the end sections of two boards cut from different portions of the tree. At *a* it will be observed that the annual rings are nearly at right angles to the surfaces of the board, while at *b* they cross the surfaces obliquely and become nearly parallel with the faces. After the boards are cut and have commenced to dry, owing to the evaporation of the sap, the sap ducts and fibers begin to contract and shrink. The form taken by the board in shrinking will be governed by the length of the annual rings on the section. At *a* the rings are practically of the same length, and as the medullary rays are nearly parallel with the surface of the board, the faces will remain straight and

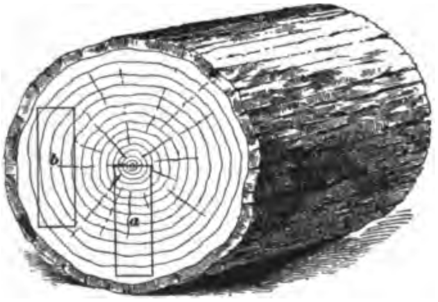

Fig. 8

true across their width. At *b*, however, the inner ring is shorter than the outer one; hence, the outer one will shrink more, causing the surface farthest from the heart of the tree to assume a concave form. This effect is further increased by the fact that the nearer the heart, the more dense and mature is the fiber, so that portions cut adjacent to the heart shrink less than those farther away from it.

Where a tree is twisted in its growth—that is, where the fibers seem to twist spirally around the stem in the height—boards that will not warp and wind, not only while they are seasoning, but also whenever affected by changes in temperature, cannot possibly be cut from it.

35. As has been shown, boards having the annual rings disposed as at *a*, Fig. 8, are less liable to shrinkage and curling, and if the timber is rich in medullary rays, the element of beauty is also enhanced; furthermore, such boards, having only the edges of the laminations exposed, wear better and more evenly than where the leaf-like figure of the grain is shown on the surface, as it would be in the case of the board *b*.

36. Methods of Sawing.—In order that as many boards as possible may be obtained from the tree, and at the same time that the boards may possess the many merits arising from the disposition of the rings on the end section, as already discussed, a method is adopted by which the logs are first cut into quarters and then reduced to the required sizes. This method is shown in Fig. 9, where *a b* and *c d* are lines showing the first saw cuts. These cuts divide the log into four quarters, *a c*, *c b*, *b d*, and *d a*, each of which is then sawed into plank

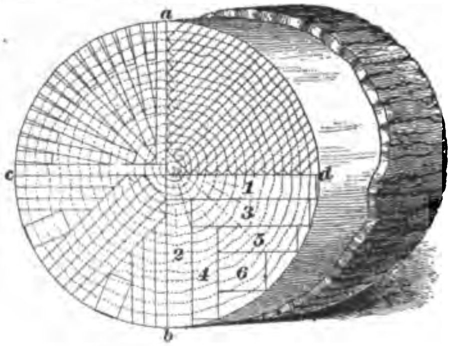

FIG. 9

by some one of the methods shown, according to the purpose for which the lumber is intended and the economy of the material, which it is necessary to observe.

37. A quarter sawed as shown from *a* to *c* gives by far the best results, as the annual rings cross the plank nearly at right angles to its face; also, the medullary rays, being parallel with this face, will exhibit the lines of the silver grain, so sought and admired in quartered oak. This method, however, is not economical in material, and more time and attention are required to divide it than is the case with any of the other methods.

The waste of material is over 25 per cent., and, though this waste can often be utilized, it is usually counted as loss in estimating the amount of timber that can be cut from a log. The time required to reduce this quarter to plank is 30 per cent. more than for the quarter *c b*, and 50 per cent. more than for the quarter *d a*. Therefore, wood quartered in this manner is expensive, and its use is confined almost exclusively to furniture and fine cabinetwork.

38. The method used in sawing the quarter from *c* to *b* is, as just stated, much more economical in time, though the waste of material is about the same. These waste pieces, however, are much larger and fewer than in the former case and can generally be utilized to better advantage. This is the usual method of cutting hardwood logs, and lumber produced in this way is used for all ordinary high-grade work in carpentry and joinery, especial attention being given to the position each plank occupied in the original log, according to the purpose for which it is required.

39. The method of sawing illustrated in the quarter from *a* to *d* can hardly be called quartering in the sense that the results of that term are considered. It is somewhat of an improvement on the method of bastard sawing, shown in Fig. 6, but there is only one-fifth of the finished lumber that presents the advantages of beauty and durability secured by either of the two former methods of sawing, and this fifth is generally selected by the dealers, and classed with the plank produced by the middle cut of the section from *c* to *b*. The other four-fifths is used almost entirely in cheap furniture and for the interior finish and trim of houses, where the terms oak floors and hardwood trim sound very well in the description, but refer to details that would give better service if constructed of pine or spruce reduced from a properly sawed log.

40. The method shown at *b d* is for securing large pieces, and the heavy planks are cut in the order that their end sections are numbered. Numbers *1* and *2* are the choice pieces, and should always be selected for floorbeams, where a long span demands a beam that is not liable to warp or twist.

The selection of certain cuts for particular purposes will be considered when those purposes are taken up for discussion, and attention is again called to the careful study of Figs. 6, 7, 8, and 9, as illustrating the influence that the original position of a stick of timber in the tree has on its subsequent behavior.

SEASONING AND KILN DRYING

41. In order that framed structures shall remain firm and rigid, the timber employed in their construction should be well seasoned. **Seasoning,** or the drying out of the sap in the woody fibers, not only reduces the material by shrinkage to the least dimension it is ever likely to have, thus permitting the joints in construction to remain close and tight, but also increases the strength. All kinds of timber are about twice as strong when thoroughly seasoned as they are in the green state.

The process of evaporating the sap is effected after the timber is sawed into commercial sizes, such as squared timber for framing purposes, planks, boards, etc., by two methods, known as *air seasoning* and *kiln drying*.

42. Air Seasoning.—In the **air-seasoning method,** the material is placed in the open air in piles, with narrow strips between the layers; a free circulation thus takes place throughout each pile, and the lumber remains in this position from 2 to 4 years, according to its ultimate purpose.

One year is considered adequate for joists, studs, sheathing, and other ordinary framing material, while work intended for trim, doors, sashes, and other products of the joiner's skill, should season for 2 years, or even more, according to the class of material.

43. Kiln Drying.—As it is impossible, however, to season wood by natural means so that it will stand well and not shrink in rooms heated to summer temperature, the lumber for interior uses must be dried by artificial means, which is known as **kiln drying.** Where this method can be employed, much time can also be saved in preparing the material for the market. *Softwoods* should primarily be air-seasoned for several months, but are usually put in the kiln as soon as cut up. One-inch boards are thus dried in from 10 to 14 days, the slower the better, as rapid drying is likely to separate the fibers by generating steam in the evaporating sap. *Hardwoods* should be air-seasoned for at least a year before being placed in the kiln, and 1-inch boards should be allowed to remain there for 2 or 3 weeks.

Kiln drying is effected by piling the lumber, as just described, in chambers, or kilns, within which a circulation of air is maintained at a temperature of about 140° F. and at a speed of about 40 miles per hour. Vacuum pumps are used to produce this rapid circulation and to remove the moisture as it evaporates from the boards.

44. Moist-Air Kiln.—A modern form of kiln is the **moist-air kiln.** By keeping the air moist, the lumber dries more evenly and with less warping than would be the case with dry air. The moist-air kiln consists of a long building with a door at each end. The green lumber is wheeled in on trucks at one door of the kiln, and is gradually moved along to make space for more incoming lumber, until it finally emerges from the opposite door completely dried. The air is heated by steam pipes under the floor—entering between the tracks at the discharging end of the kiln—and it travels slowly through the kiln by natural draft, being discharged through openings near the end where the green lumber enters. This air absorbs moisture from the lumber at the discharging end of the kiln, and, by the time it reaches the opposite end, is quite moist. Lumber takes about 1 or 2 weeks to go through the kiln, according to the size of the lumber and its greenness.

45. **Dry Shrinkage.**—Lumber kiln-dried at a temperature over 200° F. lacks the toughness and elasticity retained in the air-seasoned material, has a greater affinity for atmospheric moisture, and is often subject, especially in the softer woods, to what is known as **dry shrinkage**; that is, a shrinkage caused by the gradual closing together of the cell walls from which the moisture was evaporated in the kiln, leaving the cell in a vacuous, or hollow, condition. This dry shrinkage does not take place until after the material has been worked, and regardless of the position of the zones, or annual rings, the wood becomes concave on its freshly cut surface.

The cause of this shrinkage is that the outside, or surface, tissue of the material is dried first and thus forms a sort of casing, or crust, which holds the inner fibers in position, and when this surface is removed by means of a saw or a plane, the interior fibers, being thus relieved of their protecting casing, gradually close on the exposed side and cause the wood to bend or warp.

Shrinkage will also occur in weather-seasoned wood that is allowed to remain in one position for a long period without being cut or worked. Thus, the top of an old table will almost invariably become concave if it is planed off to get a new surface.

46. Good results are obtained by the process of subjecting weather-seasoned boards of 2 or 3 years' exposure to kiln drying before they are used in a building, or immediately after they are worked into flooring, siding, ceiling, etc. Boards thus treated and kept perfectly dry thereafter can be used in the trim and finish of a building, and if primed and painted or filled and varnished immediately after they are in place, a good, durable, and unchanging job can be assured.

PROPERTIES OF WOOD

47. Classes of Wood.—Wood as a building material may be divided into three general groups; namely, the **evergreen class,** the **hardwood class,** and the **rare wood, or cabinet wood, class.** In the first of these are classed pine, spruce, hemlock, cedar, cypress, etc. The hardwoods are oak, chestnut, walnut, locust, maple, hickory, ash, poplar, and a number of others. The expression *hardwood* is a trade name and does not necessarily imply that the wood is hard, but means that it comes from a tree not an evergreen. The rare woods are either evergreens or hardwoods but are more costly and therefore are not classed as common lumber. Each of these woods has peculiarities and characteristics that render it fit and useful for some building or other purposes, and utterly unfit and useless for others.

The weights given in the following descriptions are average ones for well-seasoned material. The weight of lumber varies according to the position it occupied in the parent tree; the nearer the root and the closer to the heart, the heavier it will be. In similar trees grown under different conditions of soil and exposure, there is often a difference of as much as 20 per cent. in weight. When timber is *green*, or newly cut, it weighs from 20 to 50 per cent. more than dry material. Framing timbers as usually bought in the market for use in buildings weigh from 15 to 20 per cent. more than when fully seasoned.

THE EVERGREEN CLASS

48. White pine (weight, 24 pounds per cubic foot), commonly known as *pine*, or sometimes referred to as *Northern pine*, to distinguish it from the species about to be described, is a tree common in the northern part of the United States and in Canada. It furnishes a light, soft, and straight-grained wood of a yellowish color, but is not so strong as other woods of the same class, and in building is used principally as a finishing material, where a good, durable, but inexpensive job is required. As a material for patternmaking, white pine has no equal, and its power of holding glue renders it invaluable to the cabinetmaker and joiner.

49. Sugar pine (weight, 22 pounds per cubic foot), or *Western pine* from the Pacific Coast, grows to an immense height; the heart wood is a pinkish brown, while the sap wood is a creamy white. The wood is straight-grained and of compact structure, is soft, easily worked, and resembles white pine. It is used in carpentry and for interior finish.

50. Idaho white pine (weight, 24 pounds per cubic foot) is not so strong as Northern white pine, but resembles it and is used for the same purposes. This wood is now being shipped to Eastern markets.

51. Long-leaf pine (weight, 38 pounds per cubic foot), also known as *hard pine*, *pitch pine*, and as *Georgia pine*, is a large forest tree growing along the southern coast of the United States, from Virginia to Texas, and extending only about 150 miles inland. Its annual rings are smaller than those of the white pine, and have a dense, dark-colored and resinous summer growth, which gives the wood a well-marked grain. Loblolly and Cuban pine are often included in this classification.

The wood is hard and strong, and, under proper conditions, very durable. For heavy framing timbers and floors, it is most desirable, and on account of its grain is sometimes used for interior trim. Where *curly pine* is used, its beautiful, wavy texture gives a fine effect.

Where timbers are excessively rich in resin, they should be avoided for structural purposes, as there is little or no strength in the fibers, which seem to be "killed" by the excess of resin. Beams of this nature, when fixed at the ends, have been torn apart lengthwise. When used for beams and joists, the wall ends should have an open air space around them.

When built solidly in the masonry, the wood is rapidly destroyed by dry rot.

The difference between long-leaf and short-leaf pine is commercially a distinction of grade and not of botanical species, although primarily they were taken from different trees.

52. **Short-leaf pine** (weight, 32 pounds per cubic foot), or *Carolina pine*, is neither so strong nor so durable as long-leaf pine. In appearance it is somewhat lighter than the long-leaf pine, and the fiber is softer and contains less resin than the regular *hard*, or *pitch*, *pine*.

53. **Bull pine** (weight, 29 pounds per cubic foot), or *California yellow pine*, is strong, has a closer grain than the other hard pines, and is exceedingly resinous. It is used for general framing purposes.

54. **Douglas fir** or **spruce** (weight, 32 pounds per cubic foot), or *Oregon pine*, is the most valuable lumber in the Pacific region for structural purposes, taking the place of the hard pines sold in the Eastern market.

55. **Black spruce** (weight, 28 pounds per cubic foot) grows in the northern half of the United States and throughout Canada. Its wood is reddish in color, and, though easy to work, is very tough in fiber and highly desirable for joists, studs, and general framing timber. This wood is also greatly used for piles and submerged cribs and cofferdams, as it not only preserves well under water, but also resists the destructive action of parasitic Crustacea, such as barnacles and mussels, longer than any other similar wood.

56. **White spruce** (weight, 25 pounds per cubic foot) is not so common as black spruce, though when sawed up into lumber it can scarcely be distinguished from the latter. Its growth is confined to the extreme northern part of the United States and to Canada.

57. **Norway spruce** (weight, 29 pounds per cubic foot) is a variety growing in Central and Northern Europe and in Northern Asia, and its tough, straight grain makes it an excellent material for ships, masts, spars, etc., as well as the

more ordinary purposes of house building. Under the name of *white deal* it fills the same place in the European woodworking shops as white pine does in America.

58. Sitka spruce (weight, 26 pounds per cubic foot), or *Western spruce*, a giant among spruces, grows along the Pacific Coast from Alaska to Central California. The wood is soft and satiny in texture and inclined to be cross-grained. It is used for interior finish, fence building, boat building, and cooperage.

59. Balsam fir (weight, 23 pounds per cubic foot), also called *single spruce*, grows in the central and the western parts of the United States. It is lighter in color, but otherwise its appearance is similar to the black and the white varieties of spruce. It is inferior, however, in every respect to black and white spruce, is very brittle, and splits easily.

60. California red fir (weight, 29 pounds per cubic foot), or *Shasta fir*, is soft, not very strong, rather close-grained, and durable in the soil. It is used for bridge timbers and general building purposes.

61. California white fir (weight, 22 pounds per cubic foot), or *silver balsam*, is soft, and not at all strong. It is not much used for building purposes but has considerable use for box lumber.

62. Hemlock (weight, 26 pounds per cubic foot) is similar to spruce in appearance, though much inferior as a building material. The wood is very brittle, splits easily, and is very liable to be *shaky*. Its grain is coarse and uneven, and though it holds nails much more firmly than does pine, the wood is generally soft and not durable. Some varieties of it are better than others, but in commerce they are so mixed that a large quantity of even quality is hard to get. Hemlock is used almost exclusively as a cheap, rough-framing timber.

63. Western hemlock (weight, about 28 pounds per cubic foot) is claimed to be harder than Eastern hemlock, and also of superior quality. As in the East, it is largely used for framing purposes, and while it shrinks and warps considerably it holds nails well.

64. White cedar (weight, 19 pounds per cubic foot), or *Arborvitæ*, is a soft, fine-grained, and very durable wood, but lacks both strength and toughness. Its durability makes it a desirable material for shingles, and also for tanks in which water is stored, and these are about the only purposes for which it is used in house building, though it is used largely for other purposes, such as boat building, cigar-box manufacture, and cooperage.

65. Red cedar (weight, 30 pounds per cubic foot) is a smaller tree than white cedar, and of much slower growth. The wood is very similar in texture to white cedar, but even more compact and durable. It has a reddish-brown color, and possesses a strong, pungent odor, which repels insects. Its extreme durability makes it valuable for posts, sills, sleepers, etc. that come in contact with the ground, and its strong odor renders it extremely serviceable as shelving for closets and linings for chests and trunks, when the exclusion of moths and other insects is desired.

66. Canoe cedar (weight, about 23 pounds per cubic foot), or *Giant Arborvitæ*, is aromatic, and is used for the same purposes as Southern red cedar. On account of its lightness, it is also used for skiff and canoe siding.

67. Incense cedar (weight, 25 pounds per cubic foot), or *California white cedar*, is soft, very brittle, closer grained than redwood, odorous, and very durable in the soil. It is much used for posts, shingles, and interior finish.

68. Redwood (weight, 26 pounds per cubic foot) is the name given to one of the species of giant trees of California, and is the most valuable timber grown in that state. This tree grows to a height of from 200 to 300 feet, and its trunk is bare and branchless for one-third of its altitude. Its color is dull red, and while the wood resembles pine and is used generally in the West for the same purposes as pine is used in the East, it is inferior to pine by reason of its softness and liability to splinter, and also on account of its peculiarity of shrinking lengthwise as well as crosswise. Redwood is used largely for railroad ties, fence posts, telegraph poles, and other purposes where durability under exposure is required. As an interior finishing material it is highly prized, as it takes a high polish, and its color improves with age. For fine work, close-grained, quarter-sawed material should be used, as a curly and wavy texture very similar to Spanish mahogany can thus be obtained. For a rich red effect, it may be stained.

69. Cypress (weight, 29 pounds per cubic foot) is a wood very similar to cedar, and grows in Southern Europe and in the southern and western portions of the United States. It is one of the most durable woods, and is well adapted for outside use. It is sometimes used for interior work and looks well under stains; it is rather brittle and fibrous, however, for this purpose. In the northern part of the United States its use is largely confined to shingles, but in the South it is used as extensively as pine is in the North.

70. Yew (weight, 40 pounds per cubic foot) is a very hard, close-grained wood and is strong and elastic. It is very durable in the soil and is invaluable for posts; it takes a high polish and is much used for turned work, paddles, bows, etc.

THE HARDWOOD CLASS

71. White oak (weight, 50 pounds per cubic foot) is the hardest of the several American species of the oak tree, and it grows in abundance throughout the eastern half of the United States. It furnishes a wood that is hard, cross-grained, strong, and of a light yellowish-brown color. It is used where great strength and durability are required, as in framed structures, ship building, cooperage, and carriage making, and also for interior finish.

72. Oregon white oak (weight, 46 pounds per cubic foot) is distinguished from Eastern white oak by a larger number of close pith rays, but is used for the same purposes.

73. **Red oak** (weight, 45 pounds per cubic foot) is similar in nearly every respect to white oak, except in its grain and color, the grain being finer and closer and the color darker and redder. It is also about 12 per cent. softer.

74. **Live oak** (weight, about 52 pounds per cubic foot), or **cañon oak,** has about the same properties as Eastern white oak, and is principally used for ship building and for durable heavy framework.

75. **Pin oak** (weight, 43 pounds per cubic foot) checks more than most varieties of oak, and is used for the same purposes as the Eastern oaks.

76. **English oak** (weight, 51 pounds per cubic foot) is similar to the American oaks in color, texture, and appearance, but is superior to them for such structural purposes as ship building and house framing. The structure of the fiber and the large, thick, and numerous medullary rays make oak especially prized as a material for cabinetwork and furniture when the log is *quarter-sawed*. The silver grain and the high and durable polish, which the wood is capable of receiving, make it one of the most beautiful used in joinery and cabinetwork.

77. **Ash** (weight, 39 pounds per cubic foot), *white* and *red* and *black*, is the wood of a large tree growing in the colder portions of the United States, and is heavy, hard, and very elastic. Its grain is coarse, and its color is very similar to that of red oak, which it also resembles in strength and hardness. Ash is used sometimes for furniture and cabinetwork, as an imitation of oak, but it is never so strongly marked in the silver grain as oak, and its tendency, after a few years, to become decayed and brittle renders it unfit for structural work. The knotted growths of the tree produce a rich figure called *burl*, which is fully explained in the articles describing the walnuts.

78. **Oregon ash** (weight, 35 pounds per cubic foot) is used for interior finish and general manufacturing purposes.

79. **White elm** (weight, from 34 to 40 pounds per cubic foot) is found in the Eastern and Middle Western States, and also in Texas. It is strong, tough, fibrous, and difficult to split, and is used for flooring, flumes, and piles. The heart wood is a light brown, and the sap wood a yellowish white, rather coarse-grained, and somewhat resembles ash.

80. **Hickory** (weight, 51 pounds per cubic foot) is the hardest, toughest, and strongest of all the American woods. The medullary rays are very numerous and distinct, and produce a fine effect in the quarter-sawed plank. The flexibility of the wood, together with its toughness and strength, render it valuable in the manufacture of carriages, sleighs, and implements requiring bent-wood members. As a building material; it is unfit for use: first, on account of its extreme hardness and difficulty of working; and second, on account of its liability to the attacks of boring insects even after the fibers have been filled and varnished.

81. **Locust** (weight, 42 pounds per cubic foot) is one of the largest forest trees in the United States, and furnishes a wood that is as hard as white oak. It is composed of very wide annual layers, in which the vessels are few, but very large, and are arranged in rows, giving the wood a peculiar striped grain. Its principal use is in exposed places where great durability is required, and for *sleepers*, on joists placed in contact with the soil or embedded in concrete. For posts for buildings and fences in damp locations it has no superior. Its hardness increases with age and on this account it is used for turned ornaments and occasionally in cabinetwork.

82. **Black walnut** (weight, 38 pounds per cubic foot) is one of the finest and largest timber trees peculiar to the United States. Its wood is heavy, hard, and porous, and its dark, purplish color is marked by a beautiful wavy grain. Strong, durable, and not subject to the attacks of insects, black walnut at one time was the most popular wood for interior decoration and fancy cabinetwork, but its present use is confined generally to small cabinetwork and gun stocks, the latter being made almost exclusively of this

material. The irregular and knotted growths of the tree produce, in the wood cut from them, a beautiful, wavy, speckled appearance, called **burl.**

83. **Butternut** (weight, 25 pounds per cubic foot), or *white walnut*, is a small species of walnut whose wood is of a light color and possesses a strongly marked grain. Its lumber can be secured only in short lengths, and though soft and easily worked with edged tools, it will not split readily, resists moisture, and remains comparatively unaffected by heat until the wood begins to char. It is not suitable as framing material, but is sometimes used in cabinetwork on account of its susceptibility to an extremely high polish.

84. **Wild cherry** (weight, 36 pounds per cubic foot), commonly spoken of simply as *cherry*, is a hard and very durable wood. The annual rings are wide and even in their structure, while the medullary rings are fine, numerous, and of a light-red color, giving the wood a close, fine grain, of a brownish-red color, which is susceptible of an exceedingly high polish, and is therefore much used in cabinetwork.

The close and even grain in cherry makes it particularly adaptable to imitations of more valuable and less abundant woods. Cherry stained black to imitate *ebony* cannot be detected from the genuine material except by scraping off the polished surface; and as a substitute for mahogany and rosewood it makes a fair imitation. For this reason, it is largely used for piano cases, book shelves, furniture, and other general cabinetwork, which is turned out in quantity and afterwards stained to imitate various other materials.

Cherry does not respond as quickly to changes of temperature or dampness as do most other woods, for which reason, it is, in many instances, more serviceable as an imitation of ebony, mahogany, or rosewood than would be the genuine material.

85. **Sweet birch** (weight, 47 pounds per cubic foot) is a wood strongly resembling cherry in its texture, and, in some species, also in its color. *Black*, or *cherry*, *birch* furnishes the best lumber, and most strongly resembles cherry in color,

texture, and strength, but it is not so durable and is much more affected by atmospheric influences.

86. **White,** or **paper, birch** (weight, 37 pounds per cubic foot) is chiefly noted for the quality of its bark, which can be stripped from the tree in long paperlike sheets. The bark was extensively used by the American Indians to thatch the roofs of their huts and to construct their canoes. The wood is used principally in the manufacture of wood-pulp paper, though small turned articles, such as spools, cups, spoons, etc., are manufactured from it.

87. **Sugar,** or **hard, maple** (weight, 43 pounds per cubic foot) is a large-sized timber tree, which furnishes a light-colored, fine-grained, hard, and strong wood. It is used for interior finish and makes most durable flooring. The annual growth is narrow and close, but on careful examination, small vessels may be seen scattered through it. The medullary rays are small and distinct, giving to the quarter-cut lumber a clearly defined silver grain. Two other characteristics of the grain are observed, especially in old trees, and are known as *curly maple* and *bird's-eye maple*. The former is a waviness of the grain similar to the burl obtained from the root timber of the walnut tree, while the bird's eye is an effect produced in old trees by the circular inflexion of the fibers formed around *spicules*, or small, sharp points, which protrude from the inner surface of the bark into the soft woody tissue. In appearance the plank is covered with numerous small spots, similar to minute knots, and resembling bird's eyes, whence it derives its name. Though both the curly and the bird's-eye maple are practically distorted fibers and materially reduce the strength of the wood, they are highly prized in the cabinetmaker's art, as they lend to the polished surface a variegation and impart a beauty equaled by few other materials.

88. **Silver,** or **soft, maple** (weight 32 pounds per cubic foot) is a wood related to hard maple, but does not possess all its valuable qualities. It is light, brittle, easily worked, moderately strong, and receives a high polish. It is not durable when exposed. It is used for interior trim and flooring.

89. **Oregon maple** (weight, 30 pounds per cubic foot) is used for the same purposes as the Eastern maple, but it is lighter, softer, and less valuable than the Eastern sugar maple. However, it is the best substitute found on the Pacific Coast.

90. **Chestnut** (weight, 28 pounds per cubic foot), a large forest tree common to the eastern part of the United States, produces a comparatively soft, coarse-grained wood, which, though very brittle, is exceedingly durable when exposed to the weather. It will not stand variations of slowly evaporating moisture as well as locust, and is therefore not so well suited for fence posts and sills laid in contact with the earth; but for exposed structures and sleepers laid in concrete or sandy soil, it affords a material much more easily worked than locust, and nearly as durable as cedar.

At the age of 50 years the tree is in fine condition for cutting, previous to which the wood is likely to be composed of large cells filled with moisture, which do not dry out without impairing the quality of the timber. On the other hand, if the tree is not cut at 50 years, it is almost sure to become decayed in the heart wood and thereby rendered unfit for use. It is a valuable wood on which to veneer, as it holds glue well.

91. **Beech** (weight, 42 pounds per cubic foot) is the wood of a large forest tree growing in the eastern part of the United States, and in Europe. It is used but slightly in building, owing to its tendency to rot in damp situations, but it is often used, especially in European countries, for piles, in places where it will be constantly submerged. This wood is very hard and tough, and of a close, uniform texture, which renders it a desirable material for tool handles and plane stocks, a use to which it is often put. Beech is occasionally used for furniture on account of its susceptibility to a high polish, but is too brittle for very fine work requiring strength.

92. Yellow poplar (weight, 26 pounds per cubic foot) is the lumber of the tulip tree, a large, straight forest tree abundant in the United States. It is often called *whitewood* or tulip, and is soft and very brittle, but shrinks excessively in drying. When thoroughly dry, it will not split with the grain, and in even slight atmospheric changes will warp and twist exceedingly. Its cheapness, ease of working, and the large size of its boards cause it to be used in carpentry and joinery in many places where it is utterly unsuited.

93. Largetooth aspen (weight 28 pounds per cubic foot), or *white poplar*, resembles yellow poplar, but is not so strong and is therefore not so much used as the latter.

94. Black cottonwood (weight, 23 pound per cubic foot), from the Pacific Coast, possesses a fine texture, but is not strong; it does not check much and shrinks moderately. It is easily worked, but is not durable when exposed.

95. Basswood (weight, 28 pounds per cubic foot) is the name given to the timber of the American *linden tree*. In color, texture, and general appearance, it strongly resembles pine, but is much more flexible. On this account it is sometimes used for curved panels in furniture and interior decorations, as well as for the curved surfaces of various vehicles in carriage manufacture. It has a great tendency to warp, and will shrink both across and parallel with the grain, rendering it undesirable in building, unless strengthened by battens or a hardwood lining.

96. Sycamore (weight, 35 pounds per cubic foot), also called *buttonwood*, is the name given in the United States to the wood of a species of tree generally known as *plane tree*. The wood is hard, of a light-brown color, and very brittle. Its grain is fine and close, but, though susceptible of a high polish, this wood is not much used in general carpentry or joinery, as it is very hard to work and has a strong tendency to warp and twist under variations of temperature. It is therefore best adapted for veneered work, when used for interior trim. In damp places, it will soon show signs of decay, and for this reason is unfitted for any but the most protected positions.

97. **California sycamore** (weight, 30 pounds per cubic foot) is used considerably in cabinetwork and cooperage, being soft and brittle, but hard to split and to work. It shrinks moderately, warps and checks considerably, but stands well. When quartered, it makes a beautiful finishing lumber—a use for which it has too long been underrated and neglected.

98. **Apple** (weight, 49 pounds per cubic foot) is much used for tool handles, plane stocks, small turned work, and squares and triangles, but is not much used in building. Its irregular-twisted branches are sometimes used in ship building for the ribs of boats, advantage being taken of the natural bend of the wood. For other building purposes, however, it is rarely used, as the lumber runs in short, irregular pieces, with a crooked and twisting grain.

99. **Pear** (weight, 47 pounds per cubic foot) has practically the same uses as the wood from apple trees, and is sometimes used for carved panels in cabinetwork, on account of yielding very easily to edged tools.

100. **Sweet gum** (weight, 37 pounds per cubic foot) is found in the Eastern and Southern States, but mostly in the basin of the Mississippi River. The heart wood is rich brown in color, suggestive of walnut, and the sap wood is nearly white. It is close-grained and compact in structure, is heavy, rather soft but strong, and receives a high polish. As sweet gum shrinks and warps a great deal in seasoning, it is best adapted for veneer work. It is also used for shingles, siding, cabinetwork, and interior finish.

101. **Hazel** (weight, 38 pounds per cubic foot) is a wood used to take the place of birch and cherry in furniture, as it stands well. It takes a high polish and looks something like one of the imported walnuts.

RARE WOODS

102. **Persian walnut** (weight, 36 pounds per cubic foot), or "French burl," is a beautiful rich, well-figured wood, the burls being a kind of wart, or excrescence, formed on the trees when young, and which is afterwards covered with the annual layers of woody tissue.

103. **Circassian walnut** (weight, 35 pounds per cubic foot) is a close-grained, rich-colored wood, much used for fine cabinetwork, especially show cases and trim in jewelry stores. Its dark, blackish-brown, striped texture permits of a high solid polish. When finished flat, it has a very effective velvety richness.

104. **Boxwood** (weight, 50 pounds per cubic foot) grows in Europe and Asia, along the coast of the Mediterranean Sea. It is close-grained, yellow in color, and very desirable, on account of the absence of shrinking or warping tendencies, for small carved or turned work, such as spindles and chessmen, and is particularly useful for wood engraving, for which purpose it has no equal. It is also largely used for making drafting scales and foot-rules. As a building material it is very rarely used.

105. **Mahogany** (weight, from 53 to 60 pounds per cubic foot) is the wood of a large, handsome tree that grows in the West Indies and Central America. Its color, grain, weight, and hardness vary considerably according to the age of the tree and the locality of its growth. There is nothing in joinery work and cabinetwork in which mahogany cannot be serviceably employed, cost being the only limit to its use.

106. **Cuban mahogany** (weight, 60 pounds per cubic foot) is a dense, hard, strong wood, of very straight growth and close texture. It has small pores filled with a chalk-like substance, and is rich brownish red in color, with dark, wavy markings.

107. **Santo Domingo mahogany** (weight, 53 pounds per cubic foot) is the richest and handsomest of all the

mahoganies. Its figure, or markings, may be curly, watered or wavy, feathered, bird's eye, or festooned, and its color is a deep, rich red with yellowish shading. The wood is strong and very resinous. It is usually cut into veneers, thirty to the inch.

Cuban and Santo Domingo mahogany are generally termed *Spanish mahogany.*

108. **Honduras** and **Mexican mahogany** (weight, about 32 pounds per cubic foot), generally called *baywood*, has a rich, golden color, is easily worked, is light, and of a somewhat soft and spongy texture. This kind of mahogany does not warp nor shrink much, but lacks the deep red richness and figure of the Spanish mahogany and is in every respect inferior to it.

109. **White mahogany** (weight, 33 pounds per cubic foot), or *prima vera*, grows in Mexico and Central America. The trees when cut are from 2 to 4 feet in diameter; the wood is a creamy white, and has a beautiful, fine, satiny grain; and the texture is quite like that of the red mahogany. It works and stands well and is used for fine cabinetwork, furniture, and interior finish. It costs somewhat more than the red variety.

110. **Rosewood** (weight, 68 pounds per cubic foot) is the hard and brittle product of several trees native to the tropical countries. It has a beautiful grain, alternating in dark-brown and red stripings, which, when subjected to a high polish, makes the surface one of the handsomest products of the vegetable world. The solid wood is used for handles of fine tools, but for few other purposes. As a veneer, it is applied to all kinds of cabinetwork, furniture, and joinery work, where richness, elegance, and durability are desirable, regardless of expense.

111. **Ebony** (weight, 76 pounds per cubic foot), a dark, almost jet-black wood, native to India and the islands in the Indian Ocean, is a strong and exceedingly hard wood with an annual growth that is almost solid. It takes an exceedingly

high polish, and is used mostly for small turned work and cabinetwork, though its veneers are applied to interior work, and also to fine furniture. It is not used so much for general interior trim and paneling as formerly, on account of its expense and the somber appearance that a black surface must necessarily lend to a room, and, besides this, the imitation of it in stained cherry is much cheaper and so like the original that an expert can scarcely detect the difference.

112. **Brown ebony** (weight, 85 pounds per cubic foot), from British Guiana, possesses a rich brown color, is very close in texture, and receives a very high, solid polish.

113. **American persimmon** (weight, 49 pounds per cubic foot), while a member of the ebony family, has a bright-yellow cast and resembles hickory; the heart wood in very old trees, however, becomes black. It is used for plane stocks and shuttles, on account of its weight and strength.

114. **Lignum vitæ** (weight, 71 pounds per cubic foot) is another exceedingly hard and dark-colored wood, with an almost solid annual growth. It is very resinous, difficult to split, and has a soapy feeling when handled. It is found in Southern Florida and the West Indies. Its color is dark brown with lighter brown markings, and it is used mostly for small turned articles, tool handles, and the sheaves of block pulleys.

115. **American holly** (weight, 36 pounds per cubic foot) grows throughout the Eastern States, and in the Middle States from Indiana to Texas. The heart wood is creamy white, which darkens and spots on exposure. This wood is very close-grained and has a compact structure, is moderately hard and heavy, and, although tough, is easily worked. It is used for inlaid work, carvings, scrollwork, and turnings, and is in moderate demand for furniture.

116. **Teak** (weight, 50 pounds per cubic foot), or *Indian oak*, is found in India, Ceylon, Burma, and Siam; it is brownish yellow in color and is straight and even-grained. The wood is moderately hard, strong, easily worked, and

stands well. It is oily and fragrant, and resists *termites*, or wood worms. As it preserves iron, it is used for backing armor plates. It is also used for flooring, inside finish, and furniture.

117. **Green heart** (weight, 72 pounds per cubic foot) is obtained in British Guiana and the West Indies. The heart wood runs from a dark green to a chestnut color and is sometimes nearly black. This wood possesses a clean, straight, compact structure, is free from knots, is exceptionally heavy, strong, tough, hard, and durable, and receives a high polish. It is used for cabinetwork and turnings and for the tips of fishing rods.

118. **Quebracho** (weight, 82 pounds per cubic foot), as its name implies, is called by the Portuguese the *hatchet-breaker.* It is close-grained, exceedingly hard and strong, and is as beautiful and dense in texture as fine ivory. There are several varieties, the principal ones being the *red* and the *white*, which grow in Chile and Mexico. It is a timber of great economic value, for in addition to its wood being used for building purposes, the bark is used medicinally, and both bark and wood are used as a tanning material. In the United States, it is employed for fine interior trim and carved work, but is very costly to work on account of its hardness. It polishes like a piece of steel.

119. **Cocobolo** (weight, 55 pounds per cubic foot) is a dark, reddish-brown, close-grained wood that grows in the West Indies. It is principally used for fine cabinetwork and inlaid work, and somewhat resembles walnut in appearance, but is slightly darker. Its fiber is rather brittle.

120. **Tulip wood** (weight, 61 pounds per cubic foot) is a beautiful, striped, rose-colored wood from Brazil. It is very close-grained, is susceptible of a high polish, and is principally used by cabinetmakers for inlaid work.

CARPENTRY

(PART 2)

PROVINCE OF CARPENTRY

1. The **art of carpentry** consists of the theoretical and practical knowledge necessary to properly execute all classes of structural work composed of wood.

The province of carpentry is a most extensive one, and the subject is generally qualified by prefixing a term denoting the class or character of the carpentry implied; as, for example, house carpentry, bridge carpentry, or ship carpentry. Wagon making, carriage making, car building, etc. also partake of the principles and practice of the same trade.

The instruction in this Course will be limited to that of *house carpentry* and will include the essential features that define the anatomy of construction of which all classes of buildings are more or less composed, except those classified as *fireproof structures*, in which the members are made of iron or steel.

2. The carpenter is distinguished from the joiner in that his efforts are directed toward the formation and disposition of the "bones," or constituent parts, of the "skeleton" of the building, or to such parts as have reference to structure only. His operations all tend toward the stability and efficiency of the framework of the edifice, while those of the joiner tend toward clothing, or encompassing the framework with finished woodwork.

The joiner does not commence his labors until the framework has been completed. Therefore, it will be seen that

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the strength and life of the building depend largely on the effective character of its carpentry; the work of the joiner may be entirely removed, and yet the structure would remain intact, so far as the anatomy of its form and arrangement would be concerned.

3. **Divisions of Carpentry.**—The art of carpentry comprises three divisions, all of which are incorporated in a successful structure, namely, *analytic*, *descriptive*, and *constructive*.

The first and second divisions are contained in the *theory*, while the third constitutes the *practice* of carpentry. The first includes the analysis of the forces that generate the stresses in the framework, which is demonstrated by the *laws of mechanics;* and the disposition of the material for efficient resistance, which is regulated by a knowledge of the *strength of materials*. The second defines the lines and methods deduced by geometric rules for laying out the work, while the third comprises the manual operations of cutting, framing, arranging, and uniting the various timbers that constitute the structure.

Carpentry, as applied to house building, relates to the construction of the rough timber framework of the building in all its parts, from the foundation to the roof. In buildings that are partly constructed of stone or other material outside the carpenter's province, the carpenter is usually called on to furnish, and generally to set, all centers, templets, wood lintels, etc. that may be required for arches, angular and molded work, wall openings, etc.

4. **Classes of Structures.**—Buildings constructed entirely of wood above the foundations may be divided into two general classes: *braced-frame* and *balloon-frame structures*.

A **braced-frame building** is one in which each piece of the structure is carefully united by mortise-and-tenon joints and the angles held rigidly by diagonal pieces, and the whole skeleton is thereby made stiff and secure in itself before any of the covering material is applied.

A **balloon frame**, on the contrary, is one in which the timbers are simply butt-jointed and nailed together; therefore, it depends greatly on the sheathing, or outer covering, for strength and stiffness.

5. The braced-frame method is the one used in ancient times, and had its origin when all nails, bolts, and iron straps were made by hand and required more labor to produce them than the cutting of mortises or the halving of joints. With the advent of machine-cut nails came the balloon frame, which, though it may be a somewhat flimsy affair in itself, is, when the sheathing is put on diagonally, sufficiently strong to withstand wind pressure, and makes a good, sound, durable structure.

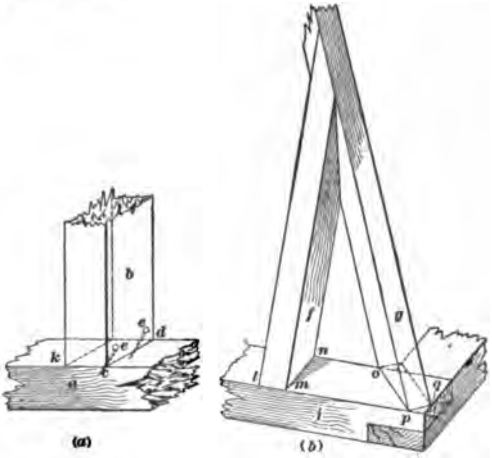
There are still, however, classes of buildings where the balloon frame is hardly suitable, and there are also instances in balloon framing where the joints require close and accurate fitting. To effect the best construction in a building, therefore, requires not only a knowledge of the kind of material best suited to the place and purpose, but also a knowledge of the proper size or sectional area of each piece, to withstand the strain that may come on it, and the proportions of its dimensions, to give the required area and at the same time suit the position in which it is to be placed.

The fitting together of these several pieces of a structure demands a knowledge of the proper kind of joint required in each particular case; an understanding of the conditions likely to arise which would tend to render the joint more or less ineffectual, such as shrinkage, dry rot, or warping; and the ability to compensate or prevent any evil results that such conditions would entail.

JOINTS AND FRAMING

FRAMING JOINTS

6. Butt Joints.—The simplest joint between two pieces of wood is the square **butt joint** shown in Fig. 1 (*a*), where the timber *b* effects a butt joint with the timber *a* on the line *k c d*. This joint, called a *barefoot joint*, is used in balloon-frame construction where the studs rest on the sills or partition caps and are secured in position by *toe-nailing*, as shown at *e*.



(*a*) (*b*)

FIG. 1

An *oblique butt joint* is shown in Fig. 1 (*b*), where *l m n* and *o p q* are the lines of the joints between the timbers *f* and *j* and *g* and *j*. This form of the joint is sometimes used for placing rafters on the plate or against the ridge board, and must always be securely toe-nailed, otherwise a movement in the position of the foot *l m* or *p q* would throw the joint out of alinement.

7. Mortise-and-Tenon Joints.—Where greater strength and security than can be obtained from the butt joint is required, a **mortise-and-tenon joint,** as shown in Fig. 2, is made use of. A rectangular hole *a b c d*, called a *mortise*, is cut into one of the timbers, as *w*, and on the end of the other timber *y* is formed a projecting pin, or *tenon*, *e f g*, which fits into and exactly fills the mortise. The *shoulders* of the tenon are shown at *h i k* and *l j*.

The proportion of the width *d a* of the mortise to the thickness of timber in which it is cut is one-third, and the mortise is cut into the center of the thickness. Or, if one timber is larger than the other, they are usually so framed that, when brought together, one face of each piece will be flush.

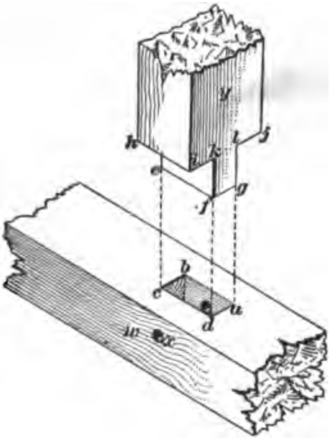


FIG. 2

8. Method of Securing Mortise-and-Tenon Joints. These mortise joints are nearly always secured in place by means of a *draw-bore pin*, which is inserted in the following manner: After the mortise is cut and the tenon is accurately fitted to it, a hole is bored in the timber squarely through both cheeks of the mortise, as shown at *x*, Fig. 2. The position of the hole *x* is accurately marked on the tenon *e f g*, and a hole is then bored through the tenon *but located from $\frac{1}{16}$ to $\frac{1}{8}$ inch nearer the shoulder* than the marks made through the hole in the mortise. When the tenon is inserted in the mortise, the relative position of the holes will be somewhat as shown in Fig. 3 (*a*), which is an enlarged section through the girt and corner post on the line *x y*. A wooden pin is then driven through these holes, and by forcing them into line, the shoulders of the tenon *p* are brought tight up against the cheeks of the mortise *q*, thus making the joint firm and secure, as well as free from any liability to work itself loose.

This wooden pin, usually called a **treenail or draw-bore pin,** should be cut from a piece of straight-grained, tough, and durable wood, preferably locust or oak, about 1 to 1½ inches square on the ends, and about 2 inches more in length than the mortised timber is in thickness. The corners are planed off, bringing the pin down to an octagonal shape on the ends, and its sides are then slightly tapered about one-fourth the length, so that it will enter the draw bore. If, through carelessness or error in measurement, the hole in the tenon is not slightly nearer the shoulder than the hole in the mortise, the joint will not be tight, and may result in what is called a *push bore*, which is a term given to this joint when the driving of the pin loosens the pieces instead of tightening them.

9. Uses of Mortise-and-Tenon Joints.—In braced-frame construction, the mortise and tenon form the joint of nearly every two important timbers that come in contact. In Fig. 3 is shown the corner of a braced-frame building, where *b* is the corner post mortised into the sill *a* at the bottom, and into the plate *h* at the top. The girts, or interties, *d*, on one of which the second tier of beams *i* rests, are mortised into the corner post and secured with a draw-bore pin as already described, while the angle braces *e* are mortised into both the girt and the corner post. The tenons on these braces are cut somewhat differently from those on the other members, owing to the diagonal position of the timbers.

In (*b*) is shown an inside view of the corner post and the joints between it and the lower braces. The top of the brace tenon *o* is cut so as to enter the corner-post mortise *p* at right angles to the face of the post, while the bottom of the tenon is in the direction to the plane of the under side of the brace, and the lower side of the mortise is cut on the same plane. The draw-bore hole in the tenon is shown at *q*, but does not show on the inside of the corner post, as it is unnecessary to bore the hole all the way through. This constitutes the system of braced-frame construction, and

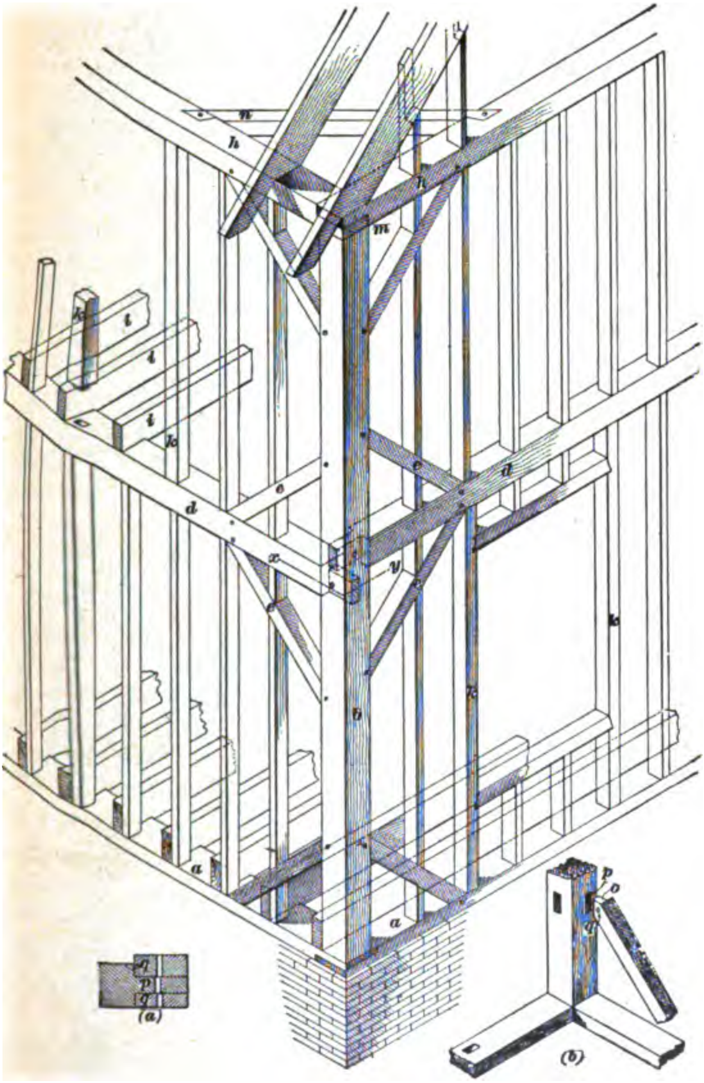
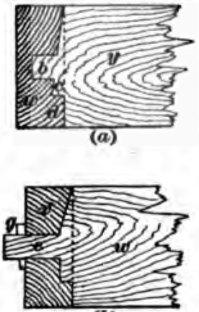


FIG. 3

though the studs are sometimes mortised into both sill and intertie, or into intertie and plate, they are thus joined simply to hold them in their places and not to add strength to the general frame. Studs adjacent to openings are usually 4 inches in thickness, as shown at *k*, and should always be mortised for good work, but generally they are formed with 2 thicknesses of the regular stud, and butt-jointed and toe-nailed to plate and girt. The intermediate studs are simply spaced 16 inches on centers and butt-jointed to form the rib-work between the posts.

10. Mortise-and-tenon joints are sometimes used for the framing of floorbeams around stair wells, chimney breasts, and other openings, as shown in Fig. 32, but in this figure the tail-beams *b* are only mortised into the header *a* which in turn is supported by the stirrup *e* instead of being mortised. This style of tenon is shown at *b* in Fig. 4 (*a*).



(*a*)

(*b*)

FIG. 4

11. Tusk Tenons.—In Fig. 4 (*a*) is shown the tenon *b* on the tail-beam *y* let into the header *w* at its center, and, to secure additional strength, a tusk *c* is cut on the tail-beam, to rest on the shoulder *d* of the header. The length of the tusk and the thickness of the tenon should each be about one-sixth the depth of the beam.

In (*b*) the tenon *e* extends entirely through the beam *v*, and is held securely in place by a wooden draw-bore pin, or wedge, as at *g*. This is the form of mortise sometimes used to secure the header to the trimmers, while the form shown at (*a*) is used to secure the tail-beams to the headers. Where the joints are made with patent beam hangers or stirrup-irons, no mortising is necessary.

12. Stirrup Irons.—Stirrup irons, or **hangers,** usually consist of pieces of wrought iron $\frac{3}{8}$ in. × $2\frac{1}{2}$ in., bent to form a hook over the trimmer beam, and a seat in which the header can rest, as shown at *e*, Fig. 32. The trimmer

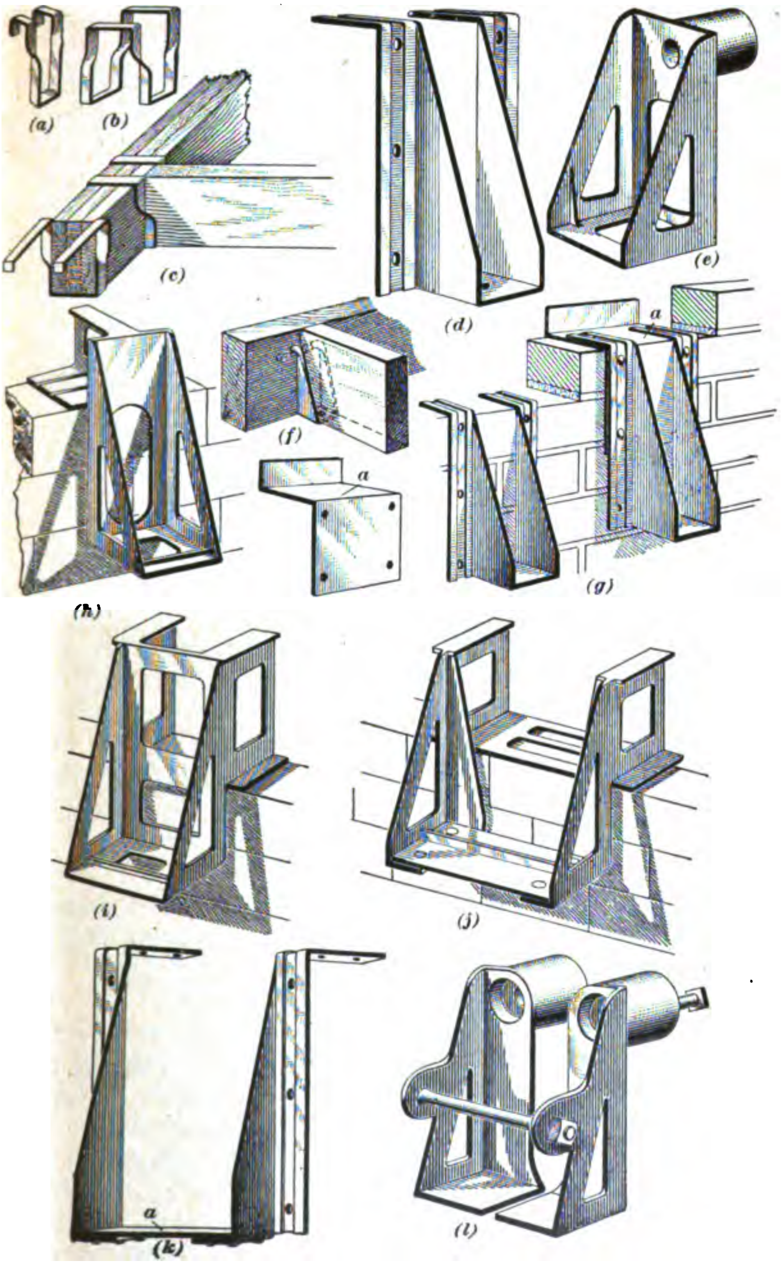


FIG. 5

and header are usually nailed together to keep the joint close, while the stirrup iron carries the weight; for good work, however, a strap or bolt should be used to keep the trimmer and header in close contact.

The use of joist and beam hangers, etc. simplifies greatly the work of framing, both for house and mill construction. In Fig. 5 are shown various styles made to meet different conditions. With these hangers a good bearing and firm support for the joists, beams, etc. may be had, and in case of fire the timbers may give way without injuring the masonry. At (*a*), (*b*), and (*c*) are shown the ordinary forms of wrought-iron stirrups, (*a*) and (*c*) being made to carry headers, while (*b*) is made double so as to carry a beam on each side of a main girder; at (*d*), (*e*), and (*f*), joist hangers for junctions of wooden headers and trimmers; and at (*g*), (*h*), (*i*), and (*j*), hangers for the support of beams at brick walls where it is undesirable to allow the beams to pass into the walls. At *a*, in (*g*), is shown the wall-bearing plate to which the stirrup is riveted. At (*k*) is shown a hanger for heavy girders or joists, adjustable to suit several sizes of timber by changing the bearing plate *a*, thus serving the same purpose as that shown at (*l*), which shows a hanger made in right and left parts, and fastened together by a bolt. Of the types of hangers shown, (*d*), (*g*), (*k*) are known as the *Van Dorn;* (*e*), (*h*), (*i*), (*j*), (*l*), the *Duplex;* and (*f*), the *Goetz.*

13. Splice Joints.—When timbers cannot be obtained of sufficient length to form an entire sill, plate, or other horizontal member, it is necessary to resort to some form of a **splice joint**, as shown in Figs. 6 and 7.

Fig. 6 shows a *plain splice joint* obtained by cutting away one-half of the thickness and width of each timber *e*, *d*, and then fitting the remaining half of each piece into the space formerly occupied by the half cut away, as indicated by the dotted lines. The piece *d* is shown at right angles to the piece *e*, which would be its position in the corner of a building, as shown at *m*, Fig. 3. By turning the piece *d* so that its end *f g i h* would coincide with the end *o p q n* of the piece *e*, the joint would splice the two pieces into a continuous timber, and the shoulder *j* will coincide with the end *m l k r*, as shown in Fig. 7, although when such a condition exists, another form of the joint, known as *beveled*, or *oblique*, *splicing*, is considered preferable.

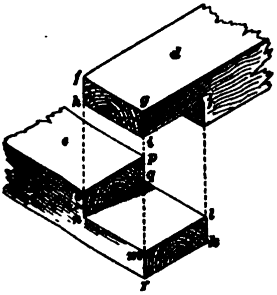


FIG. 6

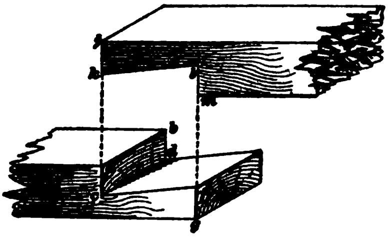


FIG. 7

This form of splice is effected by cutting away a little more than half the thickness of the timber at *a c b d* and *l m*, Fig. 7, and leaving a little more than half the thickness at the ends *f g* and *j k*. The formation of this joint requires great care, lest the timbers be weakened by cutting too deeply at *a c* and *l m*, but, when properly made, this joint does not pull apart so easily as the plain joint.

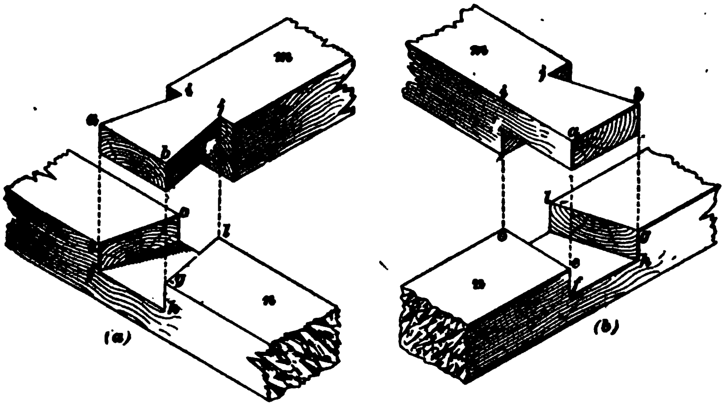


FIG. 8

14. Dovetail Halving.—Another form of joint used where prevention from sliding is a desirable condition, is known as **dovetail halving.** Fig. 8 shows two forms of this joint, which are made in the following manner: The timber *m* is first halved on the end, in the same manner as the timber *d*, Fig. 6, and the remaining half thickness is then cut to the wedge shape *a b j i*, which is called a **dovetail.** A *dovetail mortise e f h g l o* is then cut in the timber *n* half the thickness of the timber *m*, and the two pieces are driven together and held in place with spikes or screws.

The form shown at (*a*) is best adapted to positions where timber *m* is intended to be placed at right angles to the timber *n*, and although the form (*b*) is also used in similar locations, it is best adapted to locations where the timber *m* makes an acute or an obtuse angle with the timber *n*, as is shown in Fig. 3, where the timber *n* forms, at the same time, a tie and a brace to the two timbers *h* forming the plate.

15. Straddle Joints.—A **straddle, or bridge, joint,** Fig. 9, is used when a secure footing is required for the toe of a rafter or strut. The tie-beam *a* is notched on top, to receive the foot of the strut *b*; the side *d e* of the notch is in the direction of and at the same angle as the slant of the strut; while the side *d c* is at right angles to *d e*, and equal in length to the depth of the strut at *f g*. The *bridge tenon h i* is left standing when the notch *c d e* is cut, and a mortise *j k m l* is cut into the end of the strut to straddle this bridge tenon, and thus prevent the rafter from slipping.

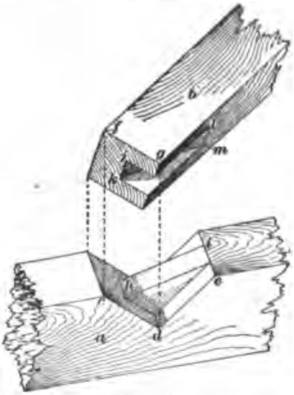


FIG. 9

Another method of treating this joint is to work the tenon *h i*, Fig. 10, on the strut timber *b*, and sink the mortise *j k* into the tie-beam *a*. The tie-beam *a* is then notched on the line *c d* a distance equal to only half the depth of the strut *b*, but is still kept at right angles to the direction of the slant of the strut, while the line *d e* has a pitch that varies in different cases, according to circumstances.

16. **Footing Rafters Without Mortise and Tenon.** A method of footing the rafters on tie-beams without the mortise and tenon is shown in Fig. 11 (*a*), where the joint is similar in every respect to the one in Fig. 10, except that the mortise and the tenon are omitted.

Fig. 11 (*b*) shows a variation made use of when the notching of the tie equal to one-third or one-half the depth of the strut would weaken the beam too much. Two notches are made, each of which should be equal to from one-sixth to one-quarter the depth of the strut, so that the sum of the two bearing surfaces *a b* and *d c* is equal to the single bearing surface *a b*, in (*a*).

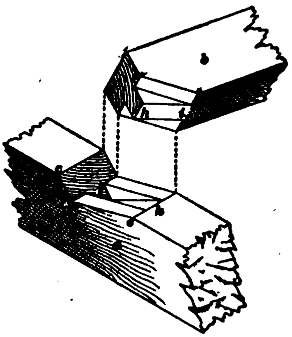
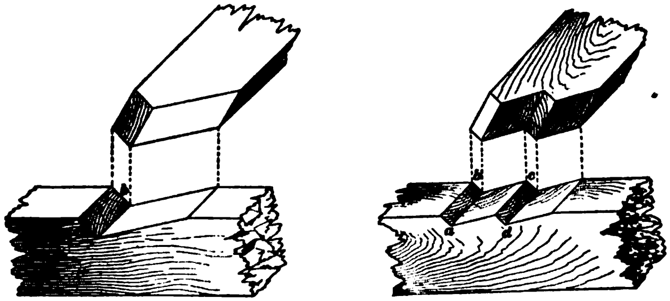


FIG. 10

17. The various joints thus far considered have been for the purpose of forming a suitable union between two pieces of timber that were in different positions and that served different purposes. With the exception of the splice joints for sills and plates, shown in Fig. 7, none of these joints could be dispensed with by getting the work out of one piece of timber.



(*a*) (*b*)

FIG. 11

Joints for the sole purpose of lengthening timbers, in such a manner as to give the most perfect union with the least amount of loss in strength, will now be considered.

18. Fishing.—A stud or post may be lengthened, or **fished**, as it is called, by the addition of an extra piece of the required length, the ends being cut square and the pieces secured together by nailing on the opposite sides of the stud two pieces of 1-inch board about 2 feet long, as shown in Fig. 12.

This method is followed only in balloon-frame construction, as in braced-frame construction, the distance between the interties and plate, or sill, should never be greater than the available length of studs. However, in balloon frames, where the studs are butt-jointed against both the sill and the plate without any intermediate joint, the studs frequently require to be fished, especially under the centers of gable roofs, where the height of the house is greatest. Studs can be obtained in all lengths from 13 to 24 feet, and any length in excess of 24 feet can be obtained only by splicing two pieces together.

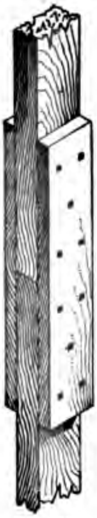


Fig. 12

19. In making a splice joint, attention should be given to the character of the strain to which the joint will be subjected, whether tension, compression, transverse strain, or torsion. Provision must then be made for the joint to resist that strain, and at the same time fulfil any other conditions of utility or beauty that may be required of it.

20. One of the simplest forms of splice for a tie-beam or other tension member is shown in Fig. 13, where the timber *a* is simply laid against the timber *b* and bolted up with the three bolts as shown at *c*. Between the bolt heads, or nuts, and the face of the timber, in each case, a washer *d* should be interposed, to

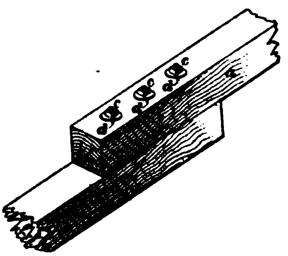


Fig. 18

prevent crushing or tearing the surface of the timber when the nut is being tightened. This makes a clumsy and awkward-looking joint, and should seldom be used except for temporary structures, but, aside from this, it is excellent for its purpose, and, by reason of the bolts, makes a stronger tension member than would the joint previously described for the splicing of studs, when spikes alone are used to secure the fish-plates.

21. Scarfing.—Where the joint is to be subjected to compression or tension, or both, and at the same time must preserve an appearance of neatness and good workmanship, resort must be made to what is called *scarfing*, or to fishing with iron plates, or both.

Scarfing consists in the cutting and fitting of the ends of two pieces of timber in such a manner that they will enter into and fit each other so as to form a comparatively secure joint, simply from the conditions of their joining surfaces. They are usually made additionally secure by means of hardwood keys and iron bolts or screws, but the primary consideration should be to make the unsecured joint as strong as possible by means of the proper proportioning of its details and parts.

22. This proportion will vary according to the strains for which the beam is intended, or to which it is likely to be subjected. In Fig. 14 is shown a form of joint applicable to a timber that would be subjected to compression, as the two abutting surfaces at *c d* and *e f* are equal to the entire cross-section of the timber, and are at right angles to the line of compression. Under tension, however, the pieces would immediately pull apart unless secured by means

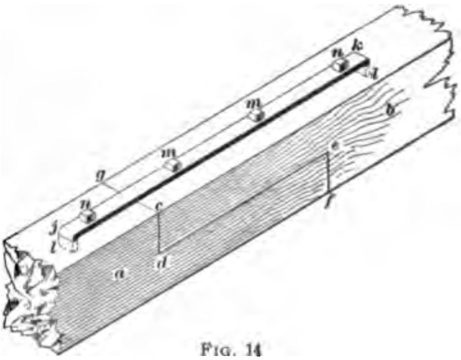


FIG. 14

of bolts and straps, as shown, in which case the entire tensile strain would have to be borne by the straps and the sections of beam immediately under them and between the bolt holes and the end of the beam; and the bolts themselves would be subjected to a shearing strain.

Again, in Fig. 15 is shown a joint that, under compressive strains, would be all that is ordinarily required, but if subjected to tension, the entire strain would be borne by the keys *r*, *s* and the iron bolts *m*. It is evident from Fig. 15 that the failing of this joint under a tensile strain would be caused by one or more of the following five conditions: (1) The keys *r*, *s* might shear through and permit the two pieces to slide apart; (2) if secured by bolts, the bolts might shear and give the same result; (3) the wood of the beam might split or shear off on some line from *o* to *d e*, allowing the pieces to pull apart without disturbing the keys; (4) the beam might part under the tension at the thinnest point, as at *b*; or (5) the bolts might remain intact, but the material between them and the end of the beam might be sheared off and permit the beams to separate.

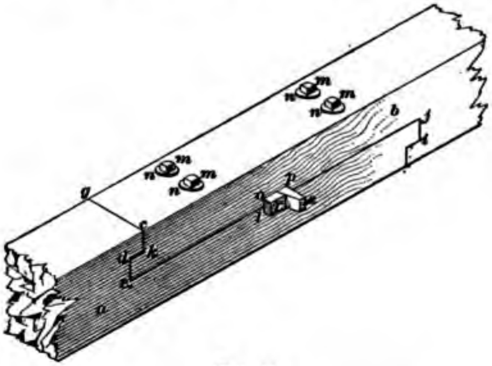


FIG. 15

23. It is evident, therefore, that in order to secure the greatest tensile strength combined with the most economical distribution of material, the following conditions must exist in any scarf joint, no matter what its form may be:

The sections of the timber subjected to a shearing strain must be so proportioned that their shearing value will be equal to the portions of the timber subjected to a tensile strain; and if the joint is additionally secured by means of iron bolts or plates, or both, the combined tensile strength of all the members subjected to tension must be equal to the combined strength of the members subjected to shear.

For example, if a joint of the form shown in Fig. 15 is used for a beam subjected to tensile strain, and the four bolts *m* are omitted, the parts must be proportioned so that the shearing strength of the keys *r*, *s*, and the shearing strength of the material between *o* and *de* or between *p* and *ij*, will equal the tensile strength of the section at *b*. For, no matter how much stronger any one of these details may be than is required, the beam will not acquire additional strength thereby, as it will only be as strong as its weakest part.

The importance of analyzing the conditions under which a beam will be strained is therefore very evident, and it is the comprehension of these conditions and the knowledge of how to provide for them that enable the proper form of scarf joint in each particular case to be selected.

24. Fig. 14 shows the simplest form of a **scarf joint** suitable for both tension and compression. The timber *a* is cut half through its depth on the line *cd*, which is perpendicular to the adjoining face of the timber, as is also the line *cg*. The timber *b* is similarly cut half its depth on the line *ef*. The material between these cuts and the end of the timber is then removed to the line *de*, and the two pieces *a* and *b* are joined in the same manner as the splice joints in Figs. 6 and 7, and are securely bolted. Thus far the joint presents the same mechanical features under tension as would the joint shown in Fig. 13, but when subjected to compression the timbers *a* and *b* have a flat bearing on the surfaces in contact at *gcd* and at *ef*, which, combined, are equal to the entire bearing surface of the end of the timber, each surface being the full breadth by half the depth. By bolting to the top and bottom of the timber an iron plate, or strap, *jk*, whose length is equal to twice the length of the joint *de*, with a breadth equal to one-third the breadth of the beam and a thickness proportioned according to the strain it is likely to be subjected to, the joint is strongly reinforced. These iron straps are usually turned over on the ends, as shown at *l*, and let into the top of the timber. The two bolts *n* merely hold the ends in place, while the bolts *m* pass through both the straps and the laps of the joint.

The iron strap prevents the timber from bending in the direction of its depth, and the bolts *m* and the bearing surfaces *gcd* and *ef* prevent it from bending in the direction of its breadth under compression, while the bolts *m*, combined with the strap *jk*, and the turned-in ends, or lugs, *l*, prevent the joint from parting under tension. This joint, especially when reinforced with the iron strap, is well adapted to a tensile strain, and its strength depends on the shearing value of the bolts *m* and the tension of the strap *jk*. The shearing value of the wood is the length between the bolts *n*, *n* plus the section that would be torn out by the lugs *l* toward the joint *gc* on each side of the beam. The sizes of bolts and straps should be proportioned to the shearing value of the wood. This joint is not fit for a transverse strain, which might bend the iron strap and tear out the bolts.

If the timber shrinks after the scarfing is complete and the beam is in place, this joint will work loose and cause trouble unless it is carefully watched and the bolts are tightened up from time to time, until the wood is thoroughly dried out and the shrinkage ceases.

The proper length of the joint on the line *de* varies with the material and the circumstances, as will be explained further on.

25. In Fig. 15 is shown another form of scarf joint well suited for tension and compression. The combined bearing surfaces of the two pieces *a* and *b* are still equal to the sectional area of the timber, and the tendency to bend in the direction of the depth is lessened by the form of the scarfed ends of the joint without the use of an iron plate, or strap.

The joint, however, is not adapted to a transverse strain, as the parts are cut away too much.

The timbers *a* and *b* are first sawed half through their depth and prepared in the same manner as for the joint in Fig. 14, but from the top of the lap, and at a distance from the end of the timber equal to half the thickness of the lap, the timber is again sawed through, until the line *c k* on timber *b* is equal to one-quarter the depth of the entire timber, or one-half the depth of the lap. The material between *c k* and the end of the lap is then removed, and on the shoulders of timbers *a* and *b*, half way between the surface and the projecting lap, the timber is sawed through in the direction of its length a distance *k d*, on timber *a*, equal to one-half the thickness of the lap. After this, the material between *k e* and the face of the shoulder is removed with a chisel, care being taken to keep the surfaces parallel and true throughout the thickness of the timber. The pieces *a* and *b* are fitted nicely together in the position shown in Fig. 15, and at the middle of the line of the joint *e j* is marked the position of the rectangular hole *l o p*, the depth *l o* being equal to about one-sixth the depth of the timber and the length of the hole *o p* twice the depth *l o*. The timbers are then separated and half the hole *l o p* is cut in each piece separately, and the distance from *o* to *e* on timber *b* is made from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch greater than the distance *l e* on timber *a*. When the pieces are finally put together, a pair of wedge-shaped keys *r*, *s* are driven into the hole, thereby forcing all the bearing surfaces into close contact. Holes are then bored through the depth of the timbers, and four bolts *m* are inserted and screwed up tight against the circular washers *n*.

26. The advantage of this joint over that shown in Fig. 14 is that the abutting parts can be better drawn together by means of the keys, and the tongues *d e* and *j i*, at the butt joints, tend to keep the surfaces of the timbers flush, even during shrinkage. Should the two pieces composing the joint shown in Fig. 15 shrink to any considerable extent, the only result would be the loosening of the bolts *m*, unless the keys *r* and *s* were made of some harder wood than the beams themselves, and therefore did not shrink so much in proportion. This would cause the joint to open slightly at the middle part of the line *e j*, but it could be prevented by making the keys about $\frac{1}{16}$ inch less in thickness than the hole at *l o*. Shrinkage would then not affect the appearance of the joint at all, and the bolts could be tightened from time to time, as in the previous case, the joints being thus maintained close and secure at all times.

This joint is better adapted to resist compression than tension, as under tension the entire strain would come on the bolts *m* and the keys *r*, *s*. Great care should therefore be exercised when this joint is to be subjected to tensile strains, to see that the bolts fit the holes tightly and that the keys are well driven, otherwise, under alternate compression and tension, the joint is liable to work loose. In a joint of this character, the most perfect fitting is required.

27. The joint shown in Fig. 16 is designed to resist tension, as in a tie-beam. The line *d l* is carried across the timber in a slanting direction, being offset at *l o*, and *o e* is drawn parallel with *d l*. The shoulders *dc* and *ef* should never be less than one-sixth the depth of the timber and should be at right angles to the slanting lines.

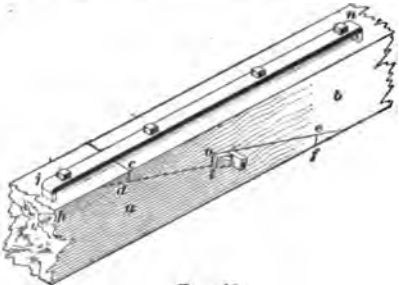


FIG. 16

This style of joint is not adapted to compression, as the oblique surfaces tend to rupture the joint when so subjected; however, under tensile strain, it is stronger than the one shown in Fig. 14, as part of the stress is taken up by the iron strap *j n*, which is applied in the same manner as in Fig. 14.

28. When a beam is subjected to a transverse strain, its top is in compression and its under side is in tension. Therefore, when a beam is under a transverse strain, such as supporting a floor or other similar load, a joint as shown in Fig. 17 should be used. The line *a b* runs at right angles to the top of the beam, thus forming a square shoulder, and extends down one-third the depth of the beam. This adapts the upper half to a compressive strain, while the under side is scarfed on the line *b c d*. The length of the scarf may be from about three to four times the depth of the beam. The iron strap placed as shown in the figure takes up the tension on the under side of the beam.

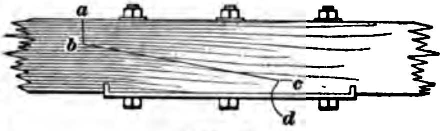


FIG. 17

29. Fig. 18 shows a modification of the joint shown in Fig. 16, in that the line *d e* is continuous and passes through the center of the keyway *r s*, and also in that the meeting line of the two timbers is cut at an obtuse angle *c h g*. This renders the beam much more reliable under a cross-strain tending to bend it in the direction of its width, and the pointed toe also tends to keep the timbers flush. Like Fig. 16, this joint is better suited to a tensile than to a compressive strain. If used in a position where it will be subjected to a transverse strain, it should have the upper half prepared as described in the preceding article.

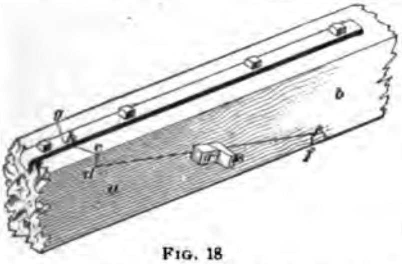


FIG. 18

30. In Fig. 19 is shown a good method of splicing the *chord*, or tie-beam, of a roof truss when the chord is required to resist both transverse and tensile stresses. The length of this scarf should be about four times the depth of the beam.

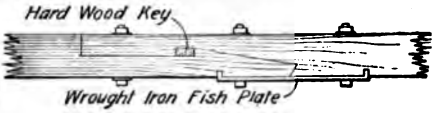


FIG. 19

31. A method of lengthening timber and preserving a considerable degree of strength, both for longitudinal and for transverse strains, is shown in Fig. 20. Three thicknesses *a*, *b*, and *c* of timber of the same size are bolted together with four bolts *m*, the joints *fg* and *hde* being squarely sawed and tightly butted in order to secure a good bearing. The bolts must fit the holes exactly, and the nuts on their ends must be screwed as tight as possible. Where timbers are over 6 inches deep, two bolts in the depth should be used. This joint will separate, either by the "sandwich" part being torn apart, the timber shearing between the bolt holes and the end of the beams, or by the bolts shearing if the other parts have a greater resistance.

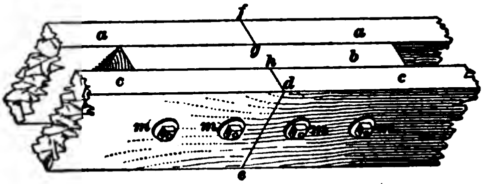


FIG. 20

32. In proportioning scarf and lap joints, such as shown in Figs. 14, 15, 16, and 18, where bolts and plates or bolts alone are to be used, the whole length of the joint should be twice the depth of the timber, if oak, ash, elm, or hard pine is used; if, however, pine or spruce is used, the joint should be from three to four times the depth of the timber.

When the timber is thoroughly seasoned, the joints shown in Figs. 16 and 18 will be self-sustaining without bolts and plates, but for the small saving acquired, it is not wise to omit them.

33. In Fig. 21 is shown a form of joint more suitable for a short post than any of the foregoing scarfed joints, but it is unfitted for tensile strain. The ends of the timbers *a* and *b* are carefully squared on the line *cde*, and in the center of the end of each piece is bored a hole to take the stud bolt shown dotted at *fg*; at a distance from the end of each, and not less than two-thirds the thickness of the post, a square hole *h* is cut, into which a nut for the bolt is inserted and through which this nut is screwed tight on each end of the stud bolt. This brings both ends of the post into close contact, so that there will not be any perceptible compression at this point when the working load is imposed.

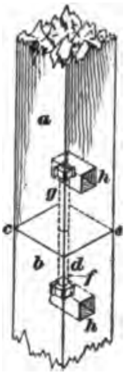


FIG. 21

34. In Fig. 22 is a cheaper form of joint for a similar purpose, though this may also be used in positions where it will occasionally be subjected to slight tensile strain. This joint is an improved form of that shown in Fig. 12, having *indents* cut at *d e f*, in order that any tensile strain will come on the wooden fish-plates, or battens, *c* and the lugs of the timbers, and not entirely on the nails, or spikes, as is the case in Fig. 12. Each of the plates *c* should have a thickness equal to not less than one-quarter the depth of the timbers *a* and *b*, and the indents *d e f* should be not more than one-third the thickness of the fish-plates. The entire length of the joint from *d* to *d'* may be three times the timber depth, and the length of the indent from *f* to *d* about one-quarter the length of the joint. The fish-plates may then be bolted through the timber from side to side with four bolts, or may be spiked to each side with from eight to twelve spikes, as shown.

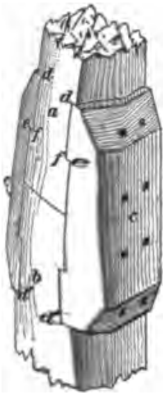


FIG. 22

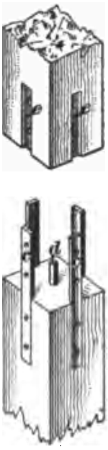


FIG. 23

35. In Fig. 23, the fish-plates are replaced by iron straps *c* not less in breadth than one-sixth the thickness of the timber. These straps are sunk into the face of the wood a depth equal to their thickness, as shown at *e*. Holes are bored or punched into these straps to receive the lag screws, or spikes, which serve to bind the timbers and straps together. The iron or hardwood dowel *d* in the center of the posts serves to keep the two pieces in alinement. This joint is suited only for compressive strains, and with Fig. 21, should be used only in a perpendicular position, unless the joint itself is independently supported.

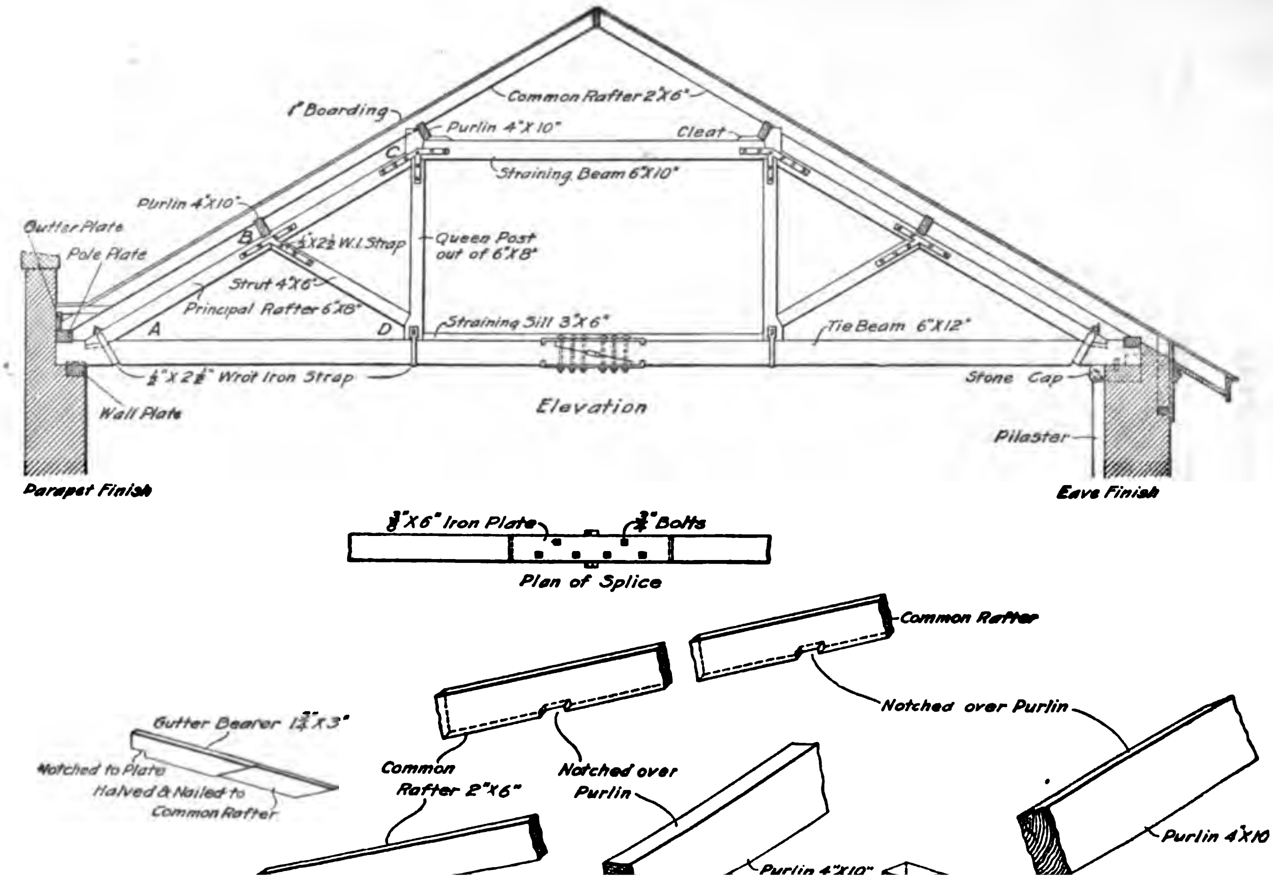
This completes the description of some of the joints most commonly used in the framing of buildings. In Fig. 24 is shown a *queenpost truss*, with detail perspective of the various joints suitable for a span of from 40 to 45 feet, in which a number of the joints described herein is shown. At one end of the truss is shown the proper construction in case a parapet wall is used; at the other end is shown the common eave construction.

FRAMING

SILLS, POSTS, AND STUDS

36. The carpentry work in a frame building usually commences when the foundation is completed. First, a timber, called the **sill** (see *a*, Fig. 3), is laid and bedded in haired mortar on the top of the foundation wall to receive the superstructure of wood. This sill varies from 6 in. × 8 in. to 8 in. × 10 in. in regular framed buildings, from 4 in. × 6 in. to 4 in. × 8 in. in balloon-framed buildings, and is laid 1 inch, or the thickness of the sheathing, from the outer face of the foundation wall. The corners of the sill are halved, as shown in Fig. 6, and when necessary to splice it in order to cover a longer run of wall than can be accomplished by one piece of the timber, the beveled-splicing joint, shown in Fig. 7, is usually adopted.

The **corner posts** are then erected at the angles of the building, as shown at *b*, Fig. 3, and are usually composed of from 6″ × 8″ to 8″ × 10″ timbers in regular frames, and of from 4″ × 6″ to 6″ × 8″ timbers in balloon frames, according to the width of the studs. In regular frames, the lower end of the corner post is generally mortised into the sill at the halved corner, and its upper end is mortised into the plate *h*, Fig. 3, while in balloon-framed work the corner posts



Elevation

Parapet Finish

Eave Finish

Plan of Splice

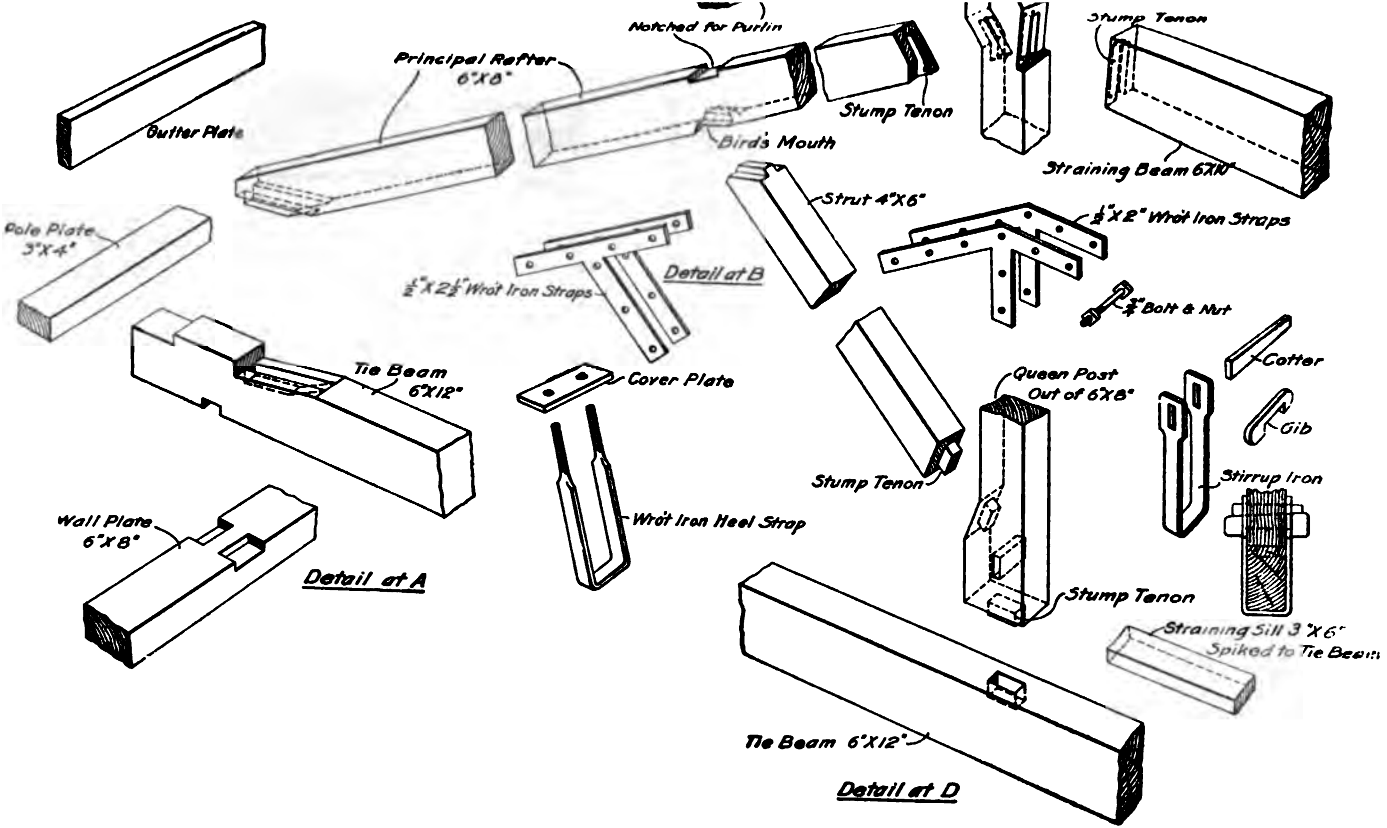

Notched for Purlin
Principal Rafter 6"X8"
Butter Plate
Stump Tenon
Bird's Mouth
Stump Tenon
Straining Beam 6X10"
Pole Plate 3"X4"
Strut 4"X6"
½"X2" Wrot Iron Straps
½"X2½" Wrot Iron Straps
Detail at B
¾" Bolt & Nut
Tie Beam 6"X12"
Cover Plate
Cotter
Queen Post Out of 6"X8"
Gib
Stump Tenon
Stirrup Iron
Wrot Iron Heel Strap
Wall Plate 6"X8"
Detail at A
Stump Tenon
Straining Sill 3"X6" Spiked to Tie Beam
Tie Beam 6"X12"
Detail at D

FIG. 24

are simply butt-jointed and spiked to the sill and the plate, the internal angle being formed by spiking a stud to the face of the corner post.

37. The **studs** *k*, Fig 3, are sometimes mortised into the sill *a*, into the girt, or intertie, *d*, and into the plate *h*, although in modern work they are more frequently simply butt-jointed in position, except in the case of double studs at the sides of openings. In balloon-framed work, however, the studs should always extend from the sill to the plate in one piece if possible; where the height is too great, they may be spliced in the manner shown in Fig. 12. To carry the floorbeams in the second or third story of a balloon frame, a *ledger board*, or *ribbon*, is notched into the studs, each beam being spiked to the adjacent stud. In regular frames, the upper floorbeams rest on the intertie, as shown at *i*, in Fig. 3.

FLOORS

38. **Wooden floors** are composed of floor boards supported by joists. These floors, in addition to the floor load they have to sustain, usually carry a ceiling of plaster, wood, or metal, the weight of which has to be considered. Where the joists span the space between bearing walls, the floor

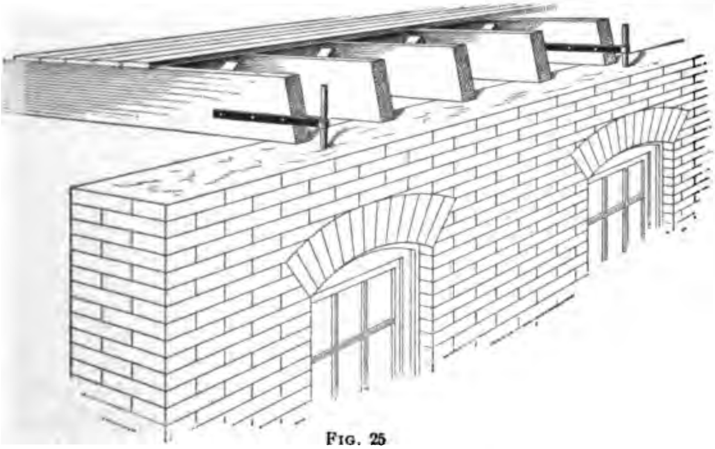


Fig. 25

load is equally distributed along the walls over solid piers and openings alike, as shown in Fig. 25.

Where the openings are wide and in buildings subjected to heavy loads, it is usual to span the building with large wooden beams or steel girders resting on solid piers and to run the floor joists parallel with the walls. By this means the loads are carried and transmitted by the solid portion of the wall to the earth, as shown in Fig. 26. Unless this is done, special headers of wood or steel must span the openings for the support of the floor joists.

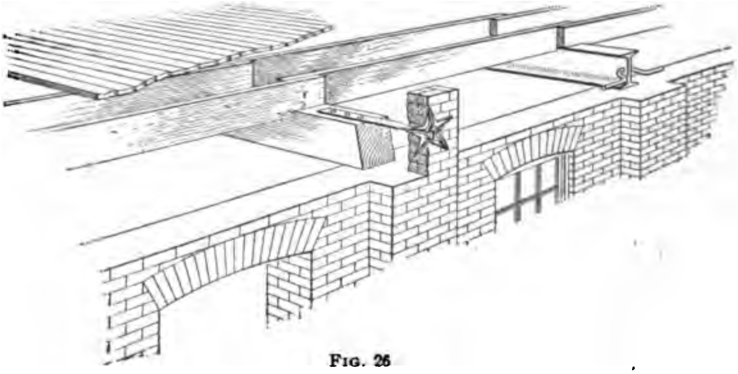


FIG. 26

39. **Joists, or floorbeams,** are *sized* or notched on the sill, or girder, as shown in Fig. 27, in order to bring their tops to an even line, any variation in the depth of the joists *b* being removed with the notch at *e d*, so that all the joists are exactly the same depth from *a* to *c*, thus securing an alinement of their upper edges. Nearly all timbers will curl or warp more or less in drying out, or seasoning, and when the joists are laid they should be placed with the convex, or *crowning*, side upwards, in order that any deflection of the joist due to the superimposed weight will bring the floor to a level line rather than produce a sag or dip in the middle of its span.

Where spans are over 16 feet, the upper edges of the joists should be *cambered*, or rounded, at the rate of $\frac{3}{4}$ inch in 20 feet, to allow for ultimate settlement. The depth of joists can be determined roughly by dividing the span in feet by 2, and adding 2; thus, for a span of 16 feet, the depth of joist would be $16 \div 2 = 8 + 2 = 10$ inches.

In the second story of a frame building the joists are notched over the interties, or girts, in the same manner as over the sill; and in balloon frames, where the girt may be but an inch in thickness, the joists are cut on the under side, forming a channel, or groove, across the joist that rests on the girt, which not only brings the tops of the joists to a level, but also forms a tie across the building. In brick or stone walls, the joists are maintained at the same level by placing small pieces of slate under the narrow ones, and thus raising them to the proper level. Thin slips of wood are sometimes used instead of slate, but as they are seldom made of a uniform thickness and squeeze readily under pressure, they are not to be recommended.

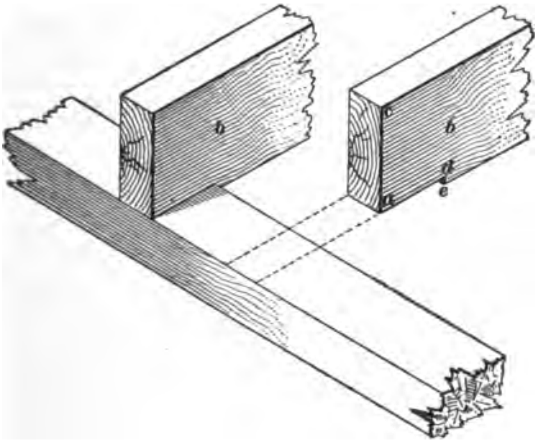


Fig. 27

40. Anchors.—A method of tying joists into a brick wall is shown at *k*, Fig. 32, where a strip of iron not less than $\frac{3}{8}$ in. × $1\frac{1}{2}$ in. in section, called an **anchor**, is nailed to the side of the joist, and the end, which is bent around a $\frac{5}{8}$-inch iron rod, is allowed to project from 4 to 8 inches beyond the end of the joist; the brickwork or stonework is

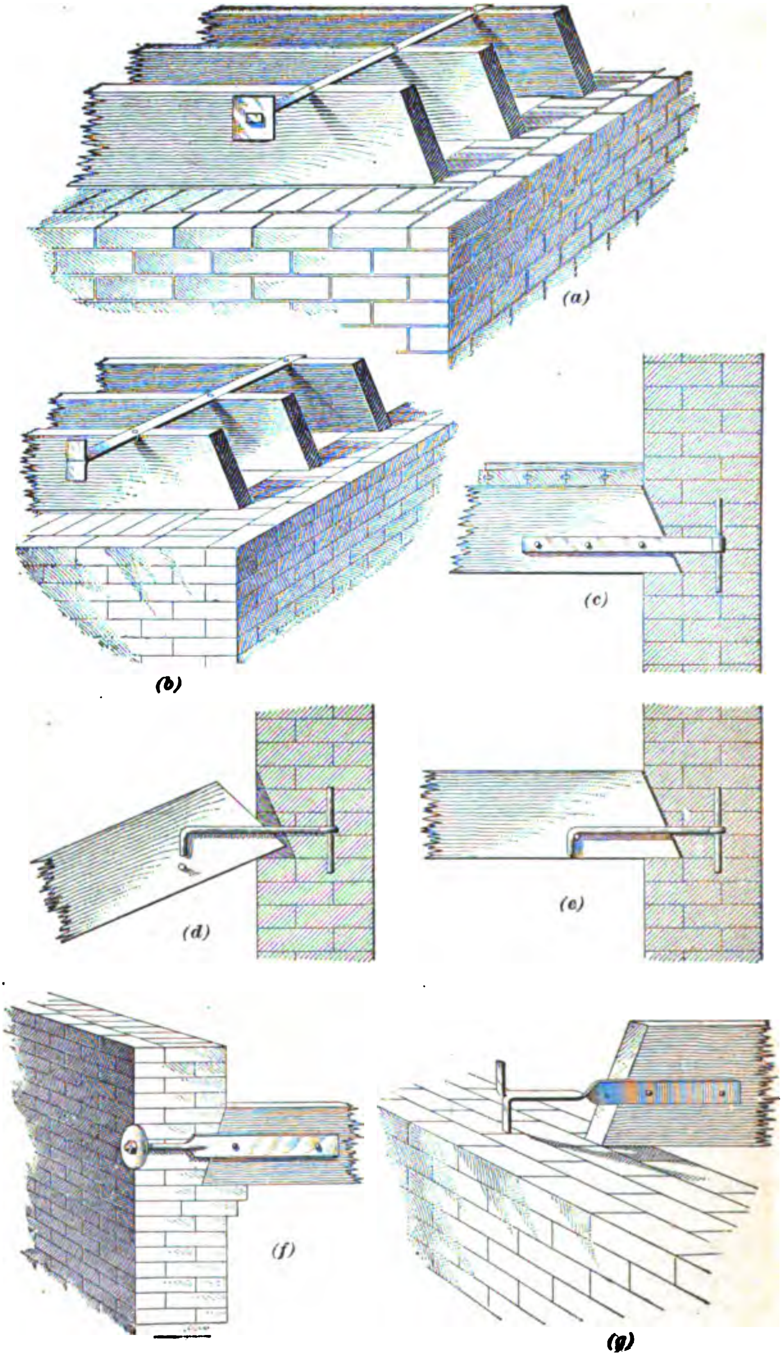


FIG. 28

then carried up tightly around it, enclosing the anchor and securing the joist.

In Fig. 28 are shown various types of iron anchors for tying wooden floor joists to stone or brick masonry; they are made of wrought bar iron forged to suit. At (*a*) and (*b*) are shown anchors to bind the walls parallel with the joists; they are usually made ⅜ in. × 2 in., and run over five joists with a lug over the last joist. The wall end may have a plate or double-forged lug, as shown. These anchors are set flush with the top of the joists, to which they are individually spiked before the flooring is laid. It will be observed that a very rigid anchorage is thus obtained. At (*c*) is shown the usual form made with a strap from 20 to 24 inches long, forged over a ⅝- or ¾-inch rod, to form the lug. The strap is spiked to the joists. At (*d*) and (*e*) is shown a rod anchor that hooks over a round rod driven into the joists, and allows the joists to fall out readily during a fire, without dislodging or overturning the brickwork. At (*f*) is shown a strap anchor passing through the wall and threaded for a nut; the washer on the outside furnishes a large bearing area. It will be observed that the brickwork in this case is corbeled out two courses, forming a bearing for the joists, which need not pass more than 2 or 3 inches into the wall. Where it is desired, the joists may thus rest on a corbeled table and not pass into the wall at all, the wall thereby retaining its full thickness and strength. In this case there should be a corbeling of at least seven courses of brick, each having a projection of ⅝ inch. At (*g*) is shown a strap anchor with a twisted end that is split to form a double lug.

41. Floor Deafening.—**Floor deafening** may be accomplished in several ways. Fig. 29 shows a method of deafening by means of a layer of heavy felt *a* spread over the floorbeams *b*, over which are nailed 2″ × 3″ furring strips *c*. Another layer of felt *d* is laid over the furring strips and the flooring *e* is laid over this. If there are two layers of flooring, it is advisable to interpose one thickness of felt between them. The felt laid over the beams and furring strips is not drawn tight, but is allowed to hang loose, as shown in the figure.

In Fig. 30 is shown a modern improvement of an old method of deafening the floor by interposing some filling

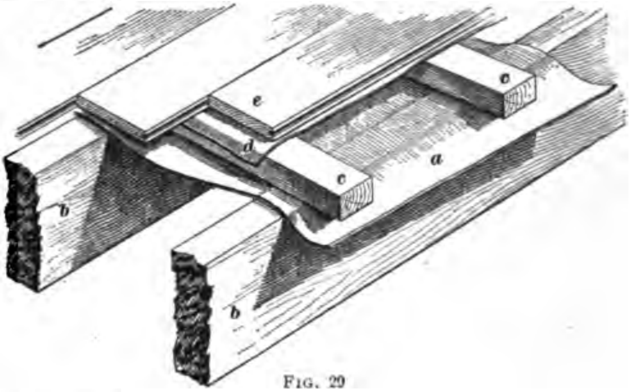


Fig. 29

material between the beams. In this case 1″ × 1⅛″ furring strips are nailed to the sides of the beams, as shown at *a*, and on these rest the deafening boards *b*, which are cut in between with their grain at right angles to the direction of

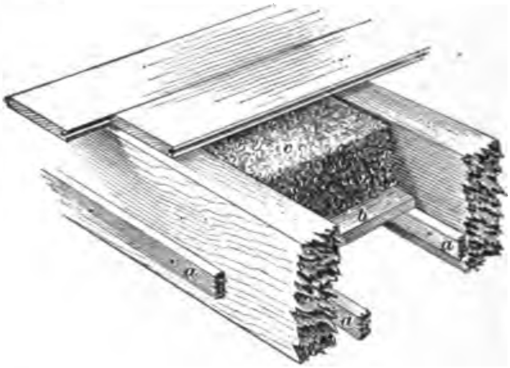


Fig. 30

the beams. The space to the tops of the beams is then filled with mineral wool, as shown at *c*, and the boards of the floor are laid on the beams in the usual manner. The layer of mineral wool may be only 3 or 4 inches in thickness, if desired. In the old method, instead of the filling of mineral wool, it was customary to put in a layer of mortar about 2 inches in thickness, composed of lime and ashes.

42. **Bridging.**—The term **bridging** is given to a system of bracing applied between joists in order to prevent them from bending sidewise or curling out of position after they are in place. Bridging also tends to strengthen the floor system when it is not uniformly loaded, by distributing the weight among the adjacent joists. Fig. 31 shows a simple and effective method by which this is accomplished, called **herring-bone bridging.** Herring-bone bridging is generally formed of 2″ × 4″ pieces *a* and *b*, Fig. 31, cut between and well nailed to the joists *c*, as shown, and spaced in rows from 5 to 6 feet apart.

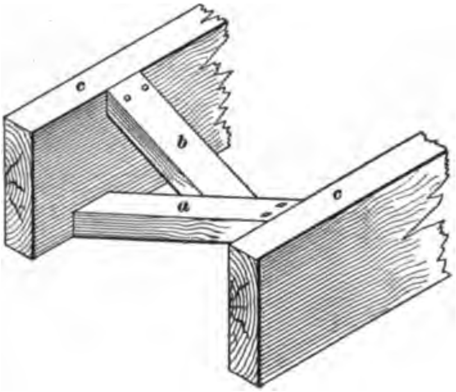


FIG. 31

Bridging is also accomplished by driving in pieces of boarding 1 inch thick between the joists and nailing them well, but the shrinkage of the joists renders them of little value.

43. **Trimmer Joists.**—Where a chimney occurs in the side wall or in the center of a building, it is necessary to frame the joists in such a manner that none of them will come within 4 inches of the brickwork enclosing a chimney flue. This is accomplished as shown in Fig. 32, the method of framing and the joints required having been already described. When there is to be a fireplace opening and hearth in front of the chimney, the header *a*, Fig. 32, should be placed from 1 ft. 9 in. to 2 ft. 6 in. away from the chimney breast, in order to provide room for a trimmer arch of brick.

This method of framing with headers, trimmers, and tail-joists is also used around the openings for stairs, skylights, dormers, and dumb-waiter shafts. It is customary to make the header *a* and the trimmers *d*, Fig. 32, twice the thickness of the regular joists *b* and *k*, as on them is imposed the combined load of all the tail-joists *b*. A safe rule is to make the trimmers at least 1 inch and the header $\frac{1}{8}$ inch thicker than the regular joists for every joist carried by the header. The trimmers rest on the wall *c*; the header is carried by the stirrups *e*; while *f* shows the tusk tenon of the tail-joists *b*.

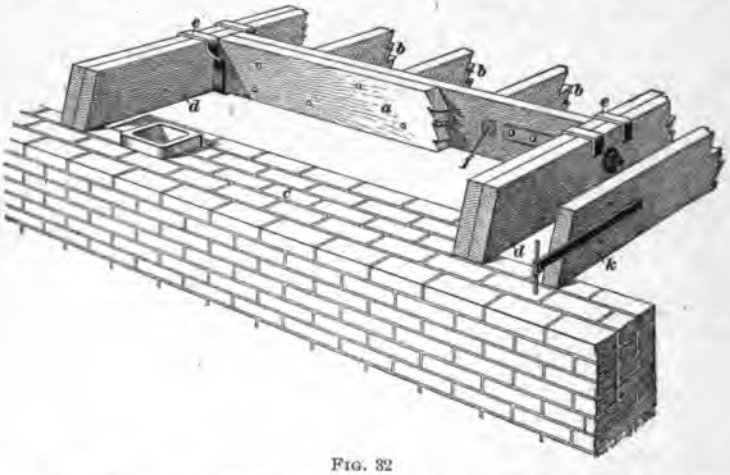


Fig. 32

44. Flooring.—The flooring is applied directly to the top of the joists after they have been brought to a true alinement, as already described, and is *plain* or *matched*, *single* or *double*, as the case and character of the building require.

A **plain floor** consists simply of second-quality boards nailed directly to the joists, each board being from 6 to 10 inches in width, and forming a plain joint edgewise with its neighbor. Such a primitive floor is seldom used except in temporary structures or when a finished floor is laid over it.

A **matched floor** is laid with selected material that has been *matched*, or *tongued and grooved*, as shown in Fig. 33.

This matching, though formerly worked entirely by hand, is now done by machinery at the mill, where the material is cut up from the seasoned timber. Matched flooring, therefore, is a commercial article purchasable at any lumber yard.

45. When laid, matched floor boards, $\frac{7}{8}$ and $1\frac{1}{8}$ inches thick are from $\frac{1}{4}$ to $\frac{3}{8}$ inch narrower than the width at which they are purchased, which shortage represents the amount cut away in the milling. At *a*, *b*, and *c*, Fig. 33, are shown three pieces of matched 4-inch flooring, which measures, when laid, but $3\frac{5}{8}$ inches, as shown, but the part *d* projects $\frac{1}{4}$ inch, making the total width of the board $3\frac{7}{8}$ inches, the remaining $\frac{1}{8}$ inch being lost partly in waste in the process of matching and partly by shrinkage after the matching has been done.

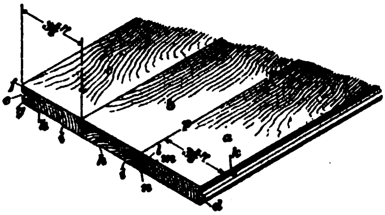


FIG. 33

At one edge of the board a projecting rib *d*, called the *tongue*, is cut, and on the opposite side a *groove e* is sunk a trifle deeper than the projection of the tongue. The upper edge *f* of the groove projects about $\frac{1}{32}$ inch more than the lower edge so that when the flooring is laid and the groove is driven tight on to the tongue, as at *l*, the $\frac{1}{32}$-inch clearance between the front of the tongue and the bottom of the groove at *m*, and between the shoulder of the tongue and the lower edge of the groove at *n*, leaves the upper edge of the groove to be driven tight against the upper shoulder of the tongue, thereby forming a tight joint on the surface, as shown at *p*.

The same result is obtained by keeping the under shoulder of the tongue slack, in which case the grooved edge would be square. The tongue is always placed slightly below the center of the thickness, so as to give more wearing surface to the floor and render the edge of the groove less liable to curl. When this matched flooring is of hardwood, such as oak, maple, or of yellow pine, a shallow groove about $\frac{1}{32}$ inch deep is cut along the under side, as shown on pieces *b* and *c* at *h i*.

This enables the boards to be laid tight to the beams or under flooring, and causes them to be less affected by any slight unevenness of the substructure.

46. Matched flooring should always be **blind-nailed;** that is, the nails should be driven in the upper angle of the tongue, as shown at *k*, in a diagonal direction. In the hardwoods, the nails should be punched in, so that their heads are well below the surface, and as the grooved edge of the next piece covers the tongue, it hides them from sight. The boards are nailed only on the tongue edge, as the groove edge is held fast by the tongue. Next the wall, on both sides of the room, it is necessary to nail the first and last boards through the upper face.

This description of flooring would more often apply in the case of a double floor, though a first-class job of a single matched floor would demand equal care.

47. **Double Floors.**—A **double floor** consists of a rough, plain, or matched floor of boards (preferably matched), laid when all the beams are in place and bridged, and of a second, or finished, floor of the character just described in detail, laid when all the rough work in the building is complete and when the joiner work is in progress. In first-class work, the finished floor should not be laid until the base, window and door trim, etc. have been fixed in place. Over the rough floor of a building, all the coarse work is carried on, such as lathing, plastering, and the first coats of painting.

48. When two thicknesses of flooring are laid, the first, or under, floor is generally laid diagonally across the beams, as shown at *a*, Fig. 34, and the second, or finished, floor is laid on top of this, but at right angles to the beams, as shown at *b*. When the rough floor is laid at right angles to the beams, and the finished floor runs in the same direction on top of it, the shrinking of the wide boards beneath may pull two or three of the boards of the finished floor up tightly together, thereby leaving open joints in the upper floor at regular intervals, corresponding very nearly with the widths of the rough boards below. The diagonal laying of the lower flooring obviates this difficulty, and to insure an even bearing all around, it is sometimes necessary to nail between the beams, at their ends, some supporting pieces *m m*, to which the diagonal boards may be spiked. The rough floor should be well nailed to the joists, and care should be taken that the finished floor is nailed only over the joists; when driven into the boards only, the nails have little holding power and are liable to work loose. For floors $\frac{7}{8}$ inch thick, $2\frac{1}{2}$-inch cut nails should be used, and for $1\frac{1}{8}$-inch floors, 3-inch nails. A layer of asphalt felt should be laid between the rough and finished floors, which serves both as a deafening and a cut-off where floors are washed, preventing water from working through.

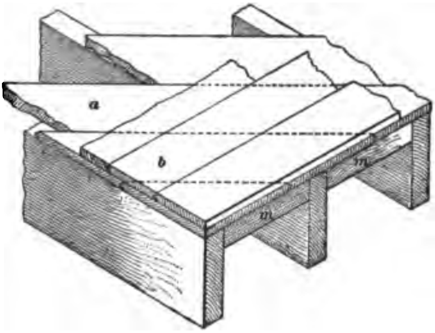


FIG. 34

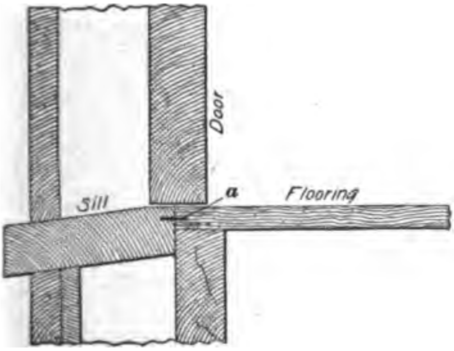


FIG. 35

The thicknesses of the boards in the lower and upper layers of a double floor are usually 1 inch and $\frac{7}{8}$ inch, respectively, but single floors in good dwellings should have the boards at least $1\frac{1}{8}$ inches thick. In mills, factories, warehouses, etc., the flooring varies from $1\frac{1}{8}$ to 4 inches in thickness. Where the wooden sill of an outside doorway is butted up against the flooring, a metal tongue should be inserted, as shown at *a* in Fig. 35.

STUDDING PARTITIONS

49. Partitions are constructed of pieces of timber from 2 in. × 4 in. to 3 in. × 6 in. in section, called **studs**, which are set vertically, with the depth of the stud in the direction of the thickness of the partition, and are spaced 12 or 16 inches on centers, in order to suit the 4-foot lengths of lath that they are to carry. Any difference that may be required in spacing should be made at one end of the room; or, where the irregularity of spacing is caused by the insertion of a door or window, the difference should be made entirely on one side of the opening. Every spacing of studs that is a variation of the foregoing will cause the laths to project past, or fall short of, the desired nailing point for their ends, necessitating in either case the cutting of the lath at the center of the nearest stud, thereby causing an expenditure of time and a waste of material.

All partitions that carry the floor and roof joists should be, so far as practicable, continuous from cellar to roof. Cellars may have brick walls that carry these bearing partitions, or they may have posts supporting girders on which rest the first tier of joists. On these beams, the studs of the first-story partitions should rest directly; the studs of the second-story partitions should rest directly on the ceiling plate of the partition under it, as shown in Fig. 37, and so on to the roof. This arrangement avoids the settlement of the upper floors—caused by the shrinkage of the joists—when the partition rests on the upper edges of the joists, as shown in Fig. 41.

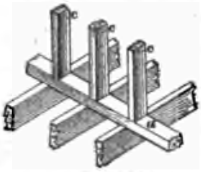


FIG. 36

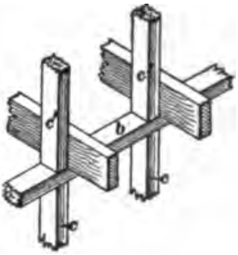


FIG. 37

50. Where a partition is placed at right angles to the joists and does not occur over a partition under it, as shown in Fig. 36, a sill *a* is first laid on the joists, and the studs *c* set thereon.

Where a partition is at right angles to the joists and has a partition directly under, as shown in Fig. 37, the studs *c′* rest on the ceiling plate *b*, which in turn is supported by the studs *c*. The studs are securely spiked to the sill and the plate.

51. In Fig. 38 is shown a method of securing a firm internal angle at the corner of a building; *a* is the corner post of a building resting on the sill *s*, and *b′*, *b*, *b* are the studs of the outside wall. The corner post in this case is made of a 4″ × 6″ piece *a*, and a 2″ × 4″ stud *b′* is spiked to it flush with the outside. This arrangement leaves the two surfaces *c* and *e*, to which the ends of the lath of each wall may be securely nailed.

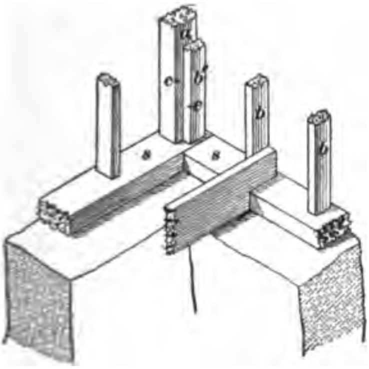


FIG. 38

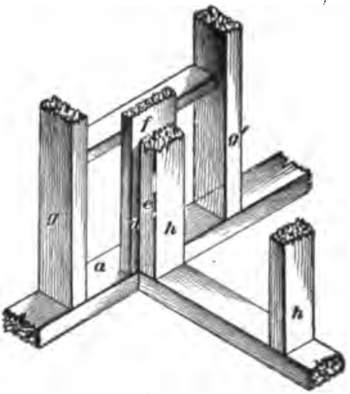


FIG. 39

52. In Fig. 39 is shown a method of forming the interior angles where partitions are placed at right angles to each other; *g*, *g′* are two studs, which may also be in the outside wall of a building, and *h*, *h* are the studs of an interior partition. At *f* on the partition, or wall, is a board 1 inch thick and 3 inches wider than the stud *h* to which it is nailed. This board extends from the sill *a* to the top of the partition, thus affording a surface on each partition where the lath ends may be nailed, as at *d* and *e*. Strips may with advantage be secured in between the studs *g*, *g′*, to which the board *f* can be nailed.

53. Where a partition must come between two floor joists and parallel to them, it should have a head, as shown in Fig. 40, in which a double plate *a* is attached to blocking *b*, and a double joist for a base, as shown in Fig. 41, if it can be so placed.

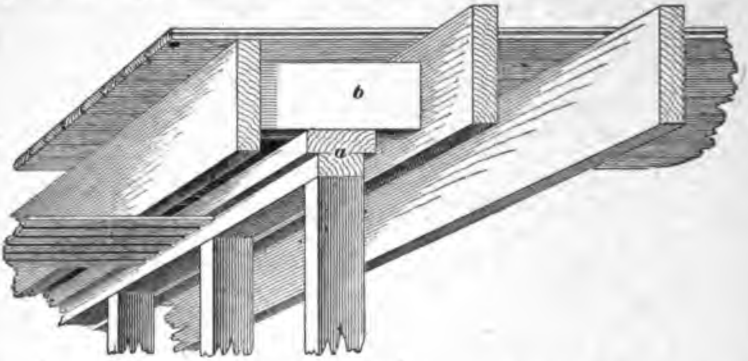


FIG. 40

54. All important partitions should be well supported at their foundations, either by a brick wall or by a beam carried on brick piers or wooden posts, with masonry footings.

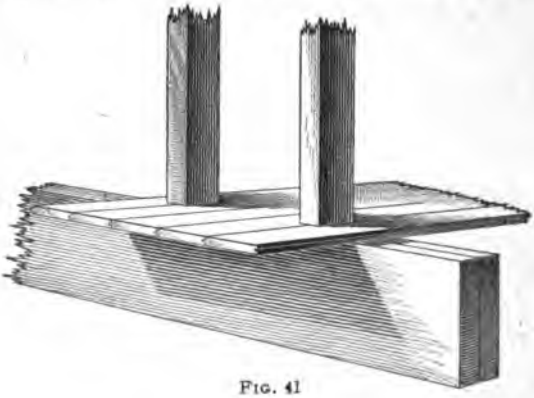


FIG. 41

Where well-seasoned material can be obtained, it is customary to set the first-floor joists directly on the beam over the cellar, as shown in Fig. 42. When this is done, it is well to keep the joists $\frac{1}{4}$ inch higher over the beam than at the walls, to allow for subsequent shrinkage of the beam. It is shrinkage of material that causes new houses to settle, and if the settlement is uniform, no harm results; but irregular settlement causes uneven floors, cracked plaster, and doors and windows that refuse to open readily or close tightly.

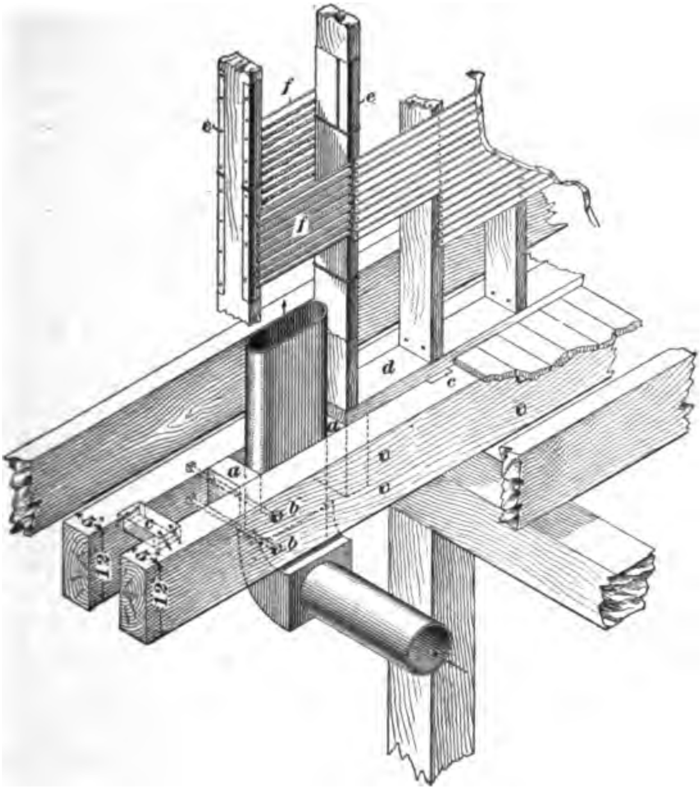


FIG. 42

Good, sound, well-dried material, therefore, should always be used, when such is obtainable, and all unsound, warped, knotty, sappy, or shaky timber should be rejected.

55. Hot-Air Pipes in Partitions.—In Fig. 42 is shown a method of supporting a partition parallel with the floor joists, as well as allowing a space through which to run a heating flue. Two 5″ × 12″ beams, or such size as the conditions require, are laid with a 6-inch space between and are bolted together through 4″ × 6″ blocks *a*, with ¾-inch bolts *b* at every second stud; 2″ × 4″ pieces *c* alternating with the blocks mentioned, except where the heating flue occurs, are notched into the beams and nailed. In cases where the cost is a consideration, the bolts may be omitted and the blocks simply spiked in place, relying on the cross-bridging for support in opposite directions. All blocks are put in on a level with the top of the beams. A 2″ × 6″ sill *d*, on which to foot the partition, is laid on these blocks. This sill is cut between the studs, where it is desired to run the tin heating flue, thus allowing the flue to run through the partition between the studs. The studs and all woodwork around the heating flues are generally covered with tin *e* or some other sheet metal, to protect the wood from the heat of the flue. Metal lath *f* is also used between the studs where the flue runs, in this way preventing the possibility of a fire, which otherwise is liable to occur should the flue become very hot. The flue should also be covered with asbestos lining, so that it may communicate as little heat as possible to its surroundings. The bend shown in the heating flue is generally adopted for good work, and is considered the best form, as it allows the hot air to ascend without obstruction.

56. Partition Deafening.—The deafening of a sheathed or plastered partition may be accomplished by inserting a layer of heavy felt between the staggered studs that support

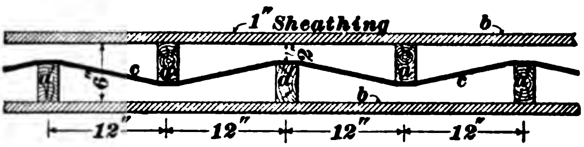


Fig. 43

the faces, as shown in Fig. 43. The studs *a*, *a′* are 2 in. × 4 in., and are spaced 12 inches on centers for sheathing, and at 8 inches for plastering. However, instead of being set to an even line, every second stud *a* is placed 2 inches back of the line of the studs *a'*, and the sheathing *b* is nailed to every second stud only, thereby making each side of the partition practically a separate structure. Before the sheathing is applied, one or two layers of heavy building felt *c* should be woven between and secured to the studs, as shown, in order to absorb any sound vibrations that may pass through the sheathing. This felt should be very heavy—about 9 square feet to the pound—and should not be drawn tight from stud to stud, but simply laid in somewhat slack and tacked in place on each stud.

57. Lathing.—Lathing is applied to the partitions as soon after the studs are in place as is convenient. Where pipes or wires are to be carried within the walls, it is sometimes necessary to delay at least a portion of the lathing until they are in place; or, when the exact location of these interior lines is determined on, the lath may be left off one side of the partition until the wiring or pipe lines have been inserted.

When lathing is applied to the ceiling of a room, it is sometimes nailed directly to the under side of the ceiling beams, though in first-class jobs it is always best to provide some means of bringing the bottoms of the ceiling beams to a level alinement before the lath is nailed on.

Laths consist of strips of soft wood, generally 1½ inches wide, ¼ inch thick, and 48 inches long. They are laid horizontally on the partitions, nailed to each stud, and maintained, as nearly as possible, at a uniform distance apart—usually from ¼ to ⅜ inch, as shown at *g*, Fig. 48.

To guard against unsightly cracks in the plaster at the angles of the rooms, suitable nailing strips, as *d* and *e*, Fig. 39, or double studs, as *a* and *b'*, Fig. 38, must always be provided. Under no circumstances must the lath be permitted to extend across from one stud to another behind the end of a partition, as from *g* to *g'*, Fig. 39.

58. Plaster Grounds.—Where any woodwork is to be applied against a plastered wall, such as a baseboard, chair rail, wainscot, picture molding, etc., it is always necessary to provide a proper bearing to nail the woodwork against, in order to avoid cracked plaster and insecure fastening, which would result from nailing through to the lath and plaster into the stud. Therefore, a **ground,** or **nailing strip,** is nailed against the studding at such a height as the top of the base, or other trim, will reach, and of a thickness equal to that of the lath and plaster. To this ground the trim is fastened when the plastering is finished and dry. When the trim to be applied is in the form of a wainscot or other wide surface, it is sometimes necessary to have several grounds at different heights, to which the separate pieces may be attached. It is always desirable in first-class work to have the walls lathed below the grounds, even down to the floor line, and also plastered to that point, as the back of the trim is thereby protected from exterior dampness and drafts, and vermin have less opportunity to make passages behind the walls.

59. Though the primary purpose of grounds is to form suitable nailing places for interior trim, they, at the same time, exercise another and most important function—that of forming a stop for the plaster. If no grounds are provided, and the plaster is simply carried to some arbitrary point that will be hidden behind the trim, an insecure job results and the edges of the plaster are liable to break off and crack as the trim is put in place, thereby necessitating patching and repairing after the job is complete. However, if a ground is placed at every side where the plaster will stop, the entire wall surface is enclosed in a frame and is secure from damage.

60. Cross-Furring.—In Art. **39** is explained the method employed to bring the top of all the floorbeams into alinement, and, as will be readily seen, any irregularity in the depths of the beams will, by this method, be thrown to the under side. Therefore, when the under side of these beams is to carry a plastered ceiling, they must first be leveled by a system of **cross-furring.** This is accomplished by nailing thereon furring strips 1 inch thick by 1½ inches wide, and spacing them 12 inches on centers.

These furring strips are either notched over the beams or dropped below them by the insertion of slips to bring them in line. The laths are then nailed on these furring strips. When a ceiling is cross-furred, it is more rigid; the plaster is less liable to crack by the vibration of the joists, and, being generally of less width than the thickness of the joists, a better key is secured for the plaster.

61. Trussed partitions are sometimes necessary where there is no supporting partition in the story below, or where a partition has a number of doors or other openings through it, so weakening it that it cannot safely carry the required weight to be imposed on it. Fig. 44 shows a trussed partition with a door 4 ft. 6 in. × 7 ft. 6 in. in the center of it. The sill *a* and the plate *b* are made 5 in. × 7 in. The studs at each side of the door are 3 in. × 5 in., and the upright wall members *g* are 6 in. × 5 in. The height of the door is limited by the 3″ × 5″ timber *e*; from the ends of the timber *p* the braces *d* extend to the ends of the sill *a*, where

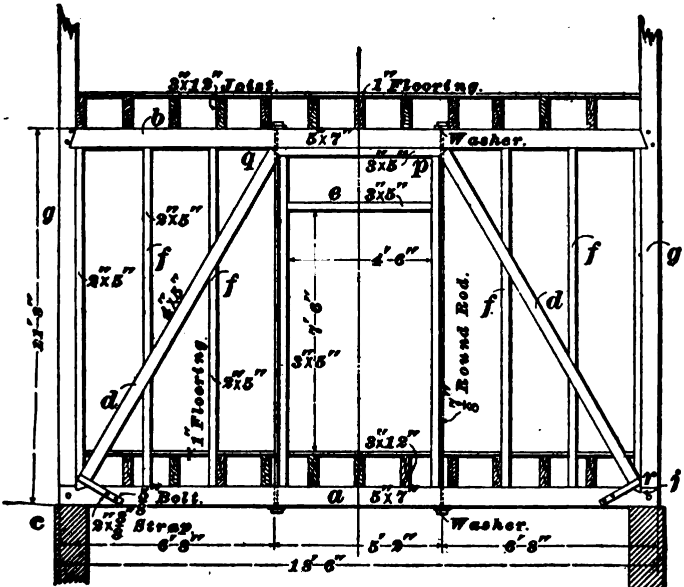


FIG. 44

they are *let in* at *j*, to secure them from slipping. A truss *c q p r* is thereby framed, around the members of which the $2'' \times 5''$ studs *f* are cut. The entire weight of this partition, together with any superimposed load, will come on the points *c* and *r*, where ample support must be provided to carry the weight down to a proper foundation.

62. Fig. 45 illustrates a partition with three openings, the essential difference between it and that shown in Fig. 44 being that the truss is entirely above the openings, while in

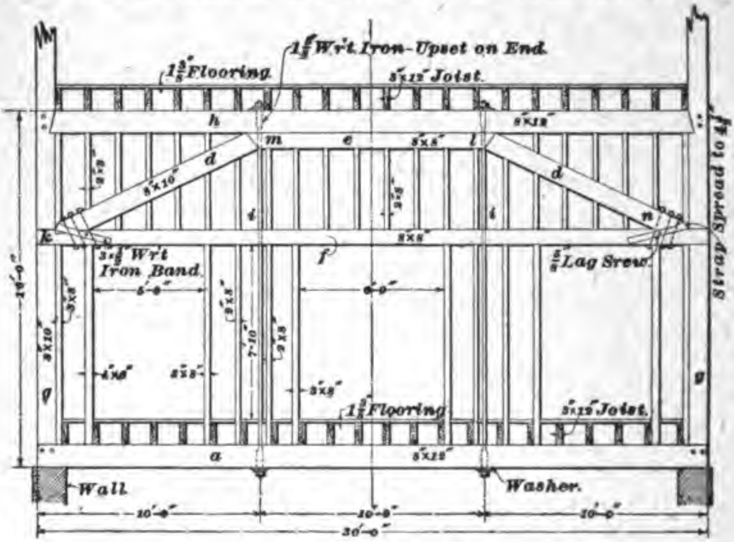


FIG. 45

the former example the opening was through the center of the truss. In Fig. 45 is shown the sill *a*, into which are mortised the wall members *g*. The tie-beam *f* marks the top of the openings, and into it the rafters, or struts, *d* are notched at each end, with the compression member *e* between their tops. This entire truss *k m l n* is carried by the wall posts *g*, and the weight of the door posts and the studs between them is carried to the top of the truss through the tie-rods *i*, which pass, also, through the plate *h*. The weight of the entire partition is therefore carried by the corner, or wall, posts *g*, which, in turn, must be well supported from below.

63. Door and Window Openings.—Door and window openings more than 3 feet wide, over which run the floor joists, should have their heads trussed, as shown in Fig. 46, the tie-beam *c* resting on the studs *d*, and the struts *e* footed into the tie-beam. This prevents the top of the door from sagging in the center, as the superimposed load is all carried to the side studs *d*.

Double studs, or larger-sized studs, should, therefore, always form the sides of door and window openings, as

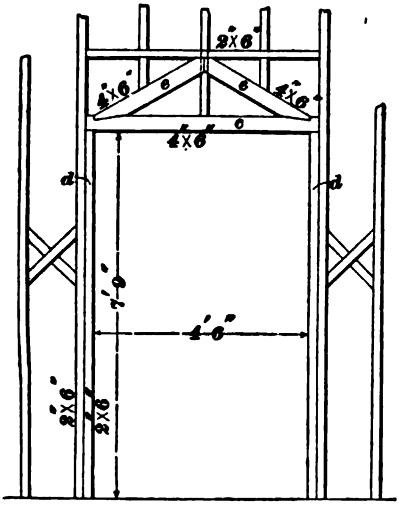


Fig. 46

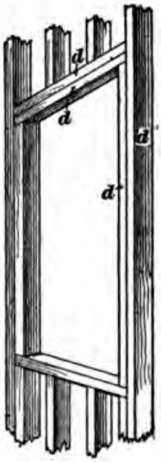


Fig. 47

shown at *d*, Figs. 46, 47, and 48, for the purpose of gaining strength and also to afford a nailing space for the trim. When a single piece of timber of the proper size for this is not at hand, it is customary to spike together two pieces of the ordinary studding and use them as a double stud, as shown at *d*, Figs. 46 and 47.

64. The sizes of doors and windows as marked on plans or working drawings are the dimensions of the finished parts, and in framing the openings for them in the studding, an allowance must be made for windows of about 2 inches in height and 7 inches in width, where there are weights; but if the window is to be hung without weights, an allowance of 1 inch at each side will be sufficient.

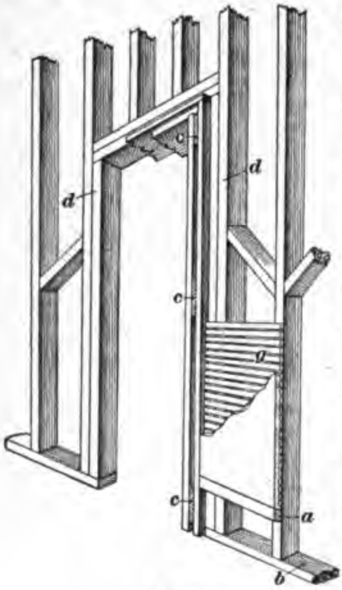


Fig. 48

In door openings, false jambs are generally inserted, as shown in Fig. 48. These jambs are nailed to the studs, and the plaster finished to them, in order to make the sides of the opening perfectly vertical and the top level. Therefore, an allowance of about 6 inches in width and 3 inches in height is required in framing the stud openings for doors, and an ordinary door 2 ft. 10 in. × 7 ft., would require a framed opening 3 ft. 4 in. × 7 ft. 3 in. When setting the finished jamb, solid blocks *c* should be placed where the hinges of the door will come, as shown in Fig. 48.

CARPENTRY

(PART 3)

ROOF CONSTRUCTION

TYPES OF ROOFS AND ROOF FRAMING

1. Pitch.—A *roof* may contribute much to the elegance and completeness of any building, as, by its fitness and appropriateness of outline, and its harmony with the structure, it crowns the whole. The angle to which any roof may be built is variously designated as **pitch, slope,** or **inclination.** The pitch may be designated by the number of degrees of inclination; the usual method, however, is to state the proportion between the vertical height of the ridge and the span of the building. Thus, if the height is 8 feet and the span 24 feet, the roof is said to have a *one-third pitch.*

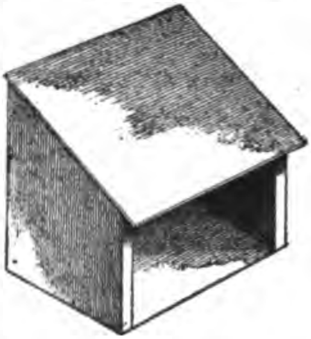


FIG. 1

2. Flat and Single Pitch. According to the manner of pitching a roof in one or more directions, there is given to it a particular name, which may express the character of the whole roof or merely name one of its characteristics. A **flat roof** is one in which there is but a slight pitch, or slant, to its timbers, just sufficient to cause water to run to its lower edge, which is called the *eaves.*

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The amount of pitch usually given to a flat roof varies from $\frac{1}{4}$ inch to 3 inches to a foot, according to circumstances. When the inclination of the roof materially exceeds 3 inches to the foot, the roof comes under the class of **single-pitch**, or **shed, roof**, sometimes called a *lean-to*, as shown in Fig. 1.

This kind of an enclosure is usually built against the side of another structure already erected—hence its name *lean-to*—and its roof often has to receive and carry the drip from the main roof above, as well as its own collection of moisture. The single-pitch roof, however, is also frequently used over verandas, attic dormer-windows, and in other minor positions on the main building.

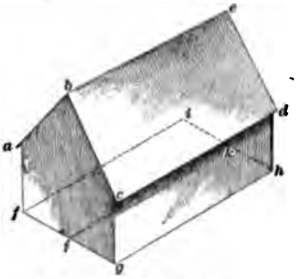


FIG. 2

3. **Double Pitch.**—When the pitch falls in both directions from the center of the building, it forms what is known as a **double pitch**, or **gable, roof**, as shown in Fig. 2, the plan of which is the rectangle *f g h i*. This form of roof derives its name from the shape of its ends, the triangle *a b c* being called a *gable*, one of which exists at each end of the building. The upper edge of the roof *b e* is called the *ridge*, and the lower edges, on each side, as at *a* and *c d*, projecting beyond the lines *f i* and *g h* in the plan, are the *eaves*, while *j k* shows the position of the ridge *b e*.

In Fig. 3 is shown a perspective of a double-pitch roof supported by kingpost trusses. The walls are extended up at the eaves line, instead of the roof projecting over as shown in Fig. 2.

4. **Valleys.**—Fig. 4 (*a*) shows in perspective a square structure with a gable on each of the four sides. The ridges of these gables intersect at *o*, while the eaves intersect in pairs at *a*, *c*, *e*, etc.; the line of intersection *o c* between the pitches *d c* and *b c* is called a **valley**. In (*b*) is shown a plan of this roof, in which the lines *d' h'* and *f' b'* mark the

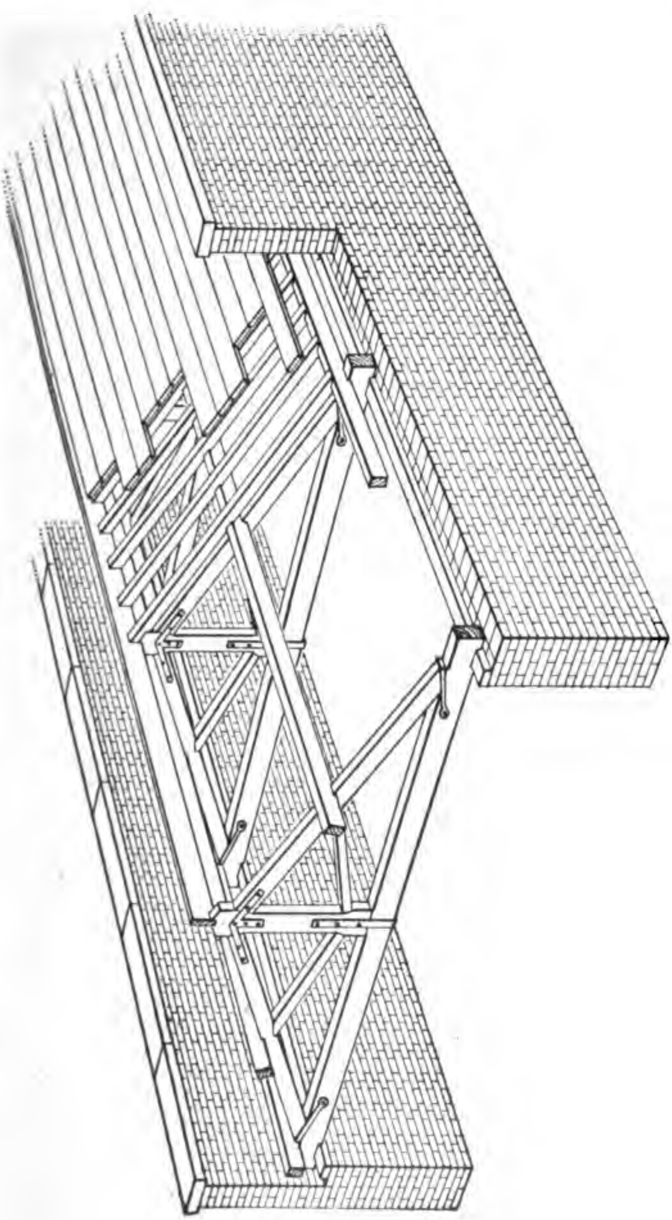
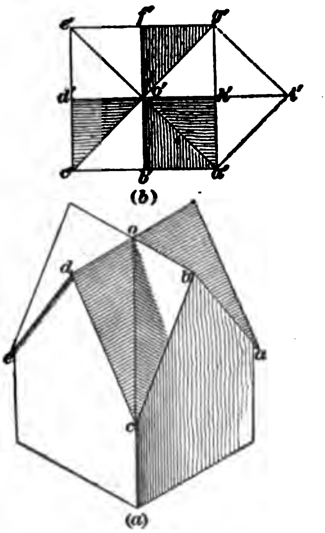


FIG. 3

positions of the ridges; the lines $o' a'$, $o' c'$, $o' e'$, and $o' g'$ show the intersections of the slanting surfaces, called *valleys*, while the dotted outline $g' i' a'$ is the form of the elevation of the gable over $g' h' a'$.

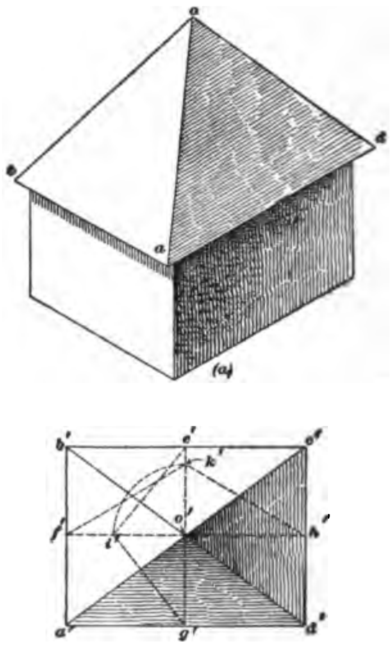
5. **Hip Roofs.**—In Fig. 5 (*a*) is illustrated a rectangular building with a roof pitched back from all four sides, forming a pyramid. The edges *o a*, *o b*, and *o d*, where these pitches meet, are called *hips*, and this type of roof is known as a **hip roof.** As the building is not square in this case, the pitch of the side *a o b* is different from the pitch of *a o d*, because the point o', as seen in the plan (*b*), is the intersecting point of all four sides (called the *apex*) and is farther from f' and h' than from e' and g'. Therefore, the proportion of rise to run is different in adjacent sides, and the pitches are necessarily different.



(*b*)

(*a*)

FIG. 4



(*a*)

(*b*)

FIG. 5

In the plan of this roof, shown at (*b*), the lines $a' c'$ and $b' d'$ show the position of the hips intersecting at o'. On the dotted line $o' e'$ is laid off the distance $o' k'$ equal to the height of the roof at the center o'; then, the lines $k' f'$ and $k' h'$ show the pitch of the rafters, which are parallel with $o' f'$ and $o' h'$. Likewise, when $o' i'$ is laid off equal to the height of the center point o', the lines $i' e'$ and $i' g'$ give the pitch of the rafters over, and parallel, to $o' e'$ and $o' g'$.

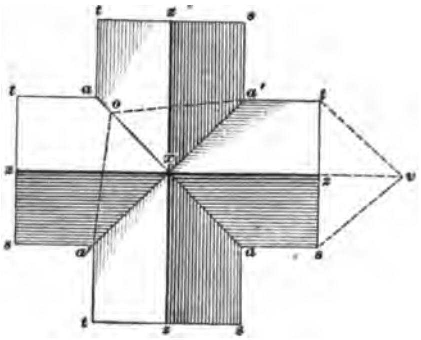


Fig. 6

6. Gable-and-Valley Roofs.—In Fig. 6 is shown the plan of a **gable-and-valley roof.** The four gables $t z s$ are precisely similar to the four gables in Fig. 4, but are brought forward from the sides of the square $a a' a a'$, giving the building the form of a cross, as shown. The dotted line $z v$ is drawn equal to the height of the ridge $z z$ above the eaves, and the lines $v t$ and $v s$ are then drawn, giving the pitch of the gables. If, on $x a$, the valley line, $x o$ is laid off equal to the height of the ridge and $o a'$ is drawn, then $o a'$ will be equal to the length of the valleys $x a$ and $x a'$.

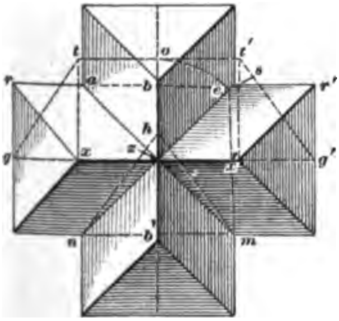


Fig. 7

7. Hip-and-Valley Roofs. The **hip-and-valley roof** in Fig. 7 is, in outline, precisely the same as the roof in Fig. 6, but in its plan of construction it has no gables. The four ends of the two parallelograms forming this plan have each two hips, as at $x r$—eight altogether—and there are four valleys, $z s$, $z m$, $z n$, and $z a$, with two ridges, $x x'$ and $b b'$. If now $x t$ and $x' t'$, each at right angles to $x x'$ and equal to the height of roof, are drawn, and the elevation of the ridge *t t′* is connected with *g* and *g′*, a vertical section of the roof *g t t′ g′* on the line *g g′* is obtained. Now, if *z e* is drawn equal to *z o*, and *e m* and *e a* are connected, a vertical section of the roof valleys *z m*, *z a* is obtained at *m e a*. To obtain a vertical section of the roof through *m n*, *b′ h* is made equal to the height *x t*, and *h m* and *h n* are connected.

8. Rafter Cuts and Lengths.—The manner of obtaining cuts and lengths of rafters about to be described is

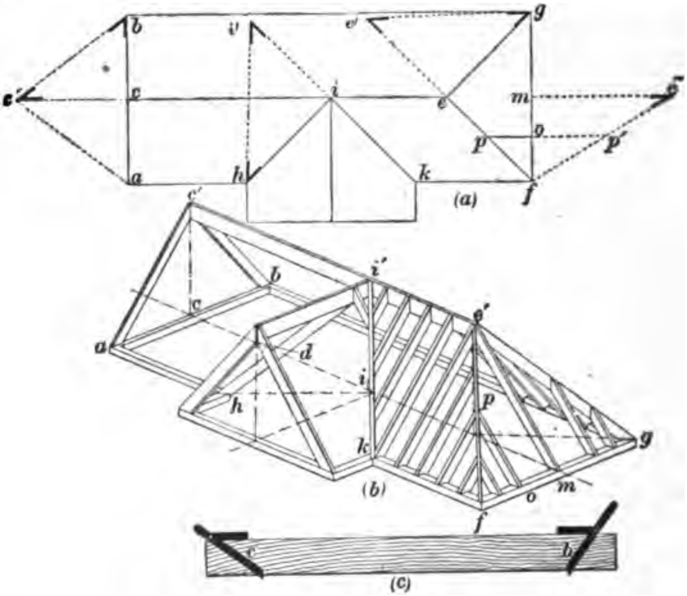


Fig. 8

known as the **graphic method.** From this method, it will be realized that a roof is composed of a series of triangles, either standing vertically or lying in an inclined position at a hip or valley line.

The first step is to lay out a roof plan on a board or sheet of drawing paper to a scale of say 1½ inches to 1 foot. Fig. 8 (*a*) illustrates a plan of a roof of uniform pitch, the wing being the same width as the main building. One end of the roof is hipped, while the other ends are finished with gables, as may be readily understood by referring to the perspective view (*b*). In both views, the same letters refer to the same parts.

9. Length and Cuts of Common Rafters.—At the center of ab, Fig. 8 (*a*), erect a perpendicular cc' equal to the height of the ridge above the wall plates; join c' and b. Then, the angle at b is the foot-cut, and that at c', the plumb-cut, of the common rafters. The length may be found by scaling. The angles are transferred to the rafter by means of a bevel, as shown in (*c*), in which b is the foot-cut, and c the plumb-cut.

10. Length and Cuts of Hip or Valley Rafters.—On the line that represents the hip on plan—as eg, Fig. 8 (*a*)—erect a perpendicular ee' equal to the height cc' of the ridge; join e' and g. Then, the angles at e' and g are the plumb- and foot-cuts, respectively, and the length may be found by scaling. The length and cuts for the valley rafter ih in this case are the same as for the hip rafter, and are found in the same way, as shown at h and i' in (*a*). Both hip and valley rafters have cheek cuts, which are the same as those of the jack-rafters.

11. Length and Cuts of Jack-Rafters.—Erect a perpendicular me'', Fig. 8 (*a*), at the center of the span fg; with f as a center and $e'g$, the true length of the hip rafter, as a radius, strike an arc cutting me'' at e''; join f and e''; then, the angle at e'' is the cheek cut. The foot- and plumb-cuts will be the same as for the common rafters. The length of any jack-rafter, as op, is found by prolonging it to cut fe'', as at p'; then, op', measured by scale, is the length of op.

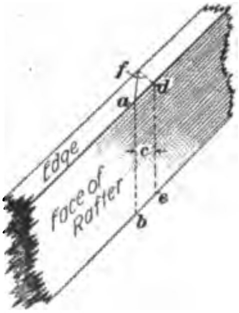


FIG. 9

12. Cheek Cut for Rafters of Any Pitch.—On the face of the rafter draw the plumb-cut, as at ab, Fig. 9. Parallel with ab draw de

at a distance *c* equal to the thickness of the rafter; square over from *d* to *f*, and join *f* and *a*, thus obtaining the cheek cut.

13. Lengths of Hip or Valley Rafters; Wall Plates at Right Angles.—Having fixed the rise and run by the square for the common rafter, take 17 inches for the run of the hip or valley rafter. Thus, if the roof is one-third pitch, that is, 8 inches rise and 12 inches run, the hip or valley rafters will have the same rise and 17 inches run. This rule gives results too great by about $\frac{5}{16}$ inch in 10 feet.

14. Lengths of Jack-Rafters.—Having obtained the lengths of the first two adjacent jack-rafters at the toe of the hip rafter by the graphic or other method, measure the difference between their lengths, and keep adding this difference for the subsequent ones.

15. Miter Cuts for Purlins.—On the squared end of the purlin draw a plumb-line, as at *ab*, Fig. 10. Draw perpendiculars, as *c* and *d*, from the corners of the purlin to this line. On the upper edge of the purlin lay off a distance *d'* equal to *d*, and on the lower edge lay off *c'* equal to *c*; from *e* draw lines to the points marked, thus obtaining the lines for the cut. This is for a cut over a hip rafter; where the cut is over a valley rafter, the bevel will be the same, but *d'* is laid off on the lower, and *c'* on the upper, edge.

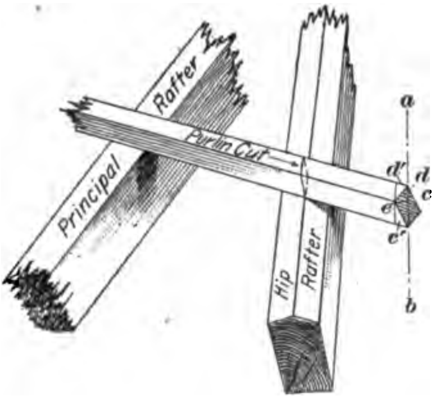


FIG. 10

16. Gambrel Roofs.—A **gambrel roof**, sometimes called a *curb roof*, is shown in Fig. 11; the term *gambrel* signifies a bend, or crook, and in this case emphasizes the break in the continuity of the roof plane. The ends of this roof are always of the gable form, as shown at *abcde*, but the slope from the ridge to the eaves is broken, the upper part *c d e* being somewhat flat and the lower parts *c b* and *e a* decidedly steep.

This form of roof had its origin in the endeavor to provide more space in the garret, or attic, of a building, by increasing the height near the eaves, where a straight gable would give no headroom. The prototype of the gambrel roof is found in the *Mansard roof*, which was the invention of a French architect whose name it bears.

The proportions of the example in Fig. 11 give the rise *f d* as equal to one-half the span *b a*, which is the common proportion of the gambrel roof.

In framing a gambrel roof, it is always necessary to have a plate, or curb, at *e h*, as well as at *a i*, the rafters between these points being cut to foot on *a i* and to carry the plate at *e h*. The rafters between the ridge *d g* and the plate *e h* are cut in the same manner for ridge and plate as in an ordinary gable roof, the plate *e h* being securely tied across the building to keep it from spreading under the thrust.

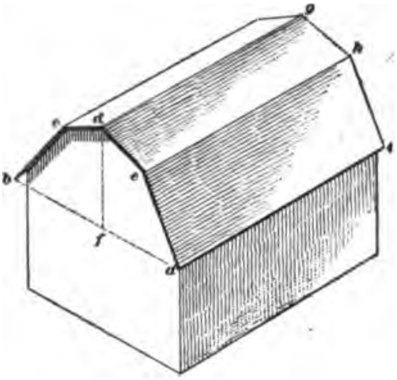


FIG. 11

17. Where the wings of a building are unequal in width, the following method may be used in preserving uniformity of pitch and equality in the height of the ceiling joists.

Fig. 12 shows a typical plan, in which the front wing is 28 feet wide and the side wings are 18 feet wide. Fig. 13 shows the method of proportioning the gables according to Belidor's rule. The line *a f* is made equal to the width of the front, plus 18 inches for each eaves projection, making 31 feet. On the center *g*, with a radius equal to one-half of this measurement, describe a semicircle *a h f*; divide this semicircle into five equal parts, as at *b*, *c*, *d*, and *e*, and erect the line *g h* perpendicular to *a f*. Draw *a b* and *f e*, the side slopes of the roof, and *b h* and *e h*, the upper slopes of the roof; then, *a b h e f* will be the outline of the gable over the front and rear of the house. The gables over the 18-foot wings, if laid out in the same manner, would give an outline as at *k m n o l*. This outline would be undesirable, as the slopes would not intersect properly and a uniform height of ceiling would not be obtained. If, however, the side pitch *k m* is continued up to

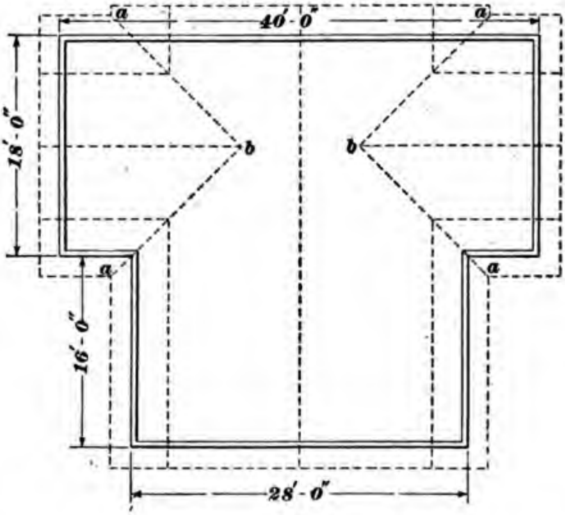


FIG. 12

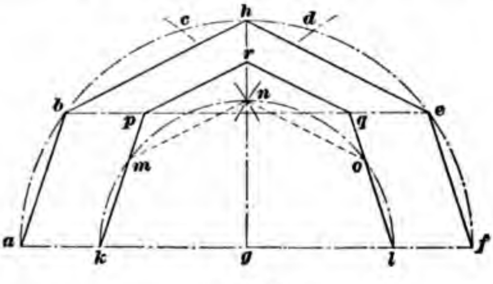


FIG. 13

the curb line of the main roof at *p*, and *p r* is drawn parallel with the upper slope of the main roof, the outline *k p r q l* will be suitable for the roofs over the wings, and the ceilings will be the same height as in the main part of the house. Both roofs will have the same pitch, and their intersection on the plan will be at an angle of 45° with the sides of the house, as at *a b*, Fig. 12. The dotted lines in Fig. 12 denote the roof plan.

The cornice at the eaves of the roof is shown simple in character, and consists of a plain crown molding and fascia, as shown at *a*, Fig. 14, which give the construction and finish of the roof shown in Fig. 15. The eaves should be given a liberal projection, and the angle between the soffit and the frieze should be finished with a bed molding, as at *b*. The cornice is continued up the slope of the gables, while the fascia and fillet of the corona, or lower members of the cornice, are carried across the front horizontally, as shown in Fig. 15.

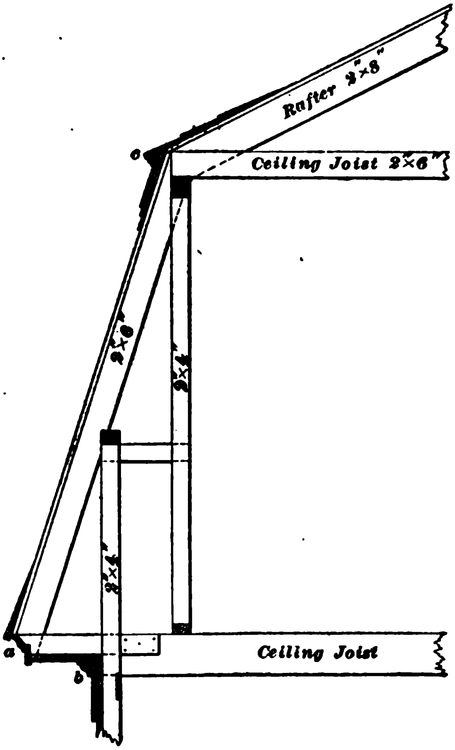


FIG. 14

The method of shingling the roof at the curb is shown at *c*, Fig. 14, where the shingles of the upper slope extend beyond those of the lower slope and the angle is closed by a simple molding. The shingles of the upper slope are laid with a slight projection beyond the edge of the molding, and those on the lower slope are carried up under the molding.

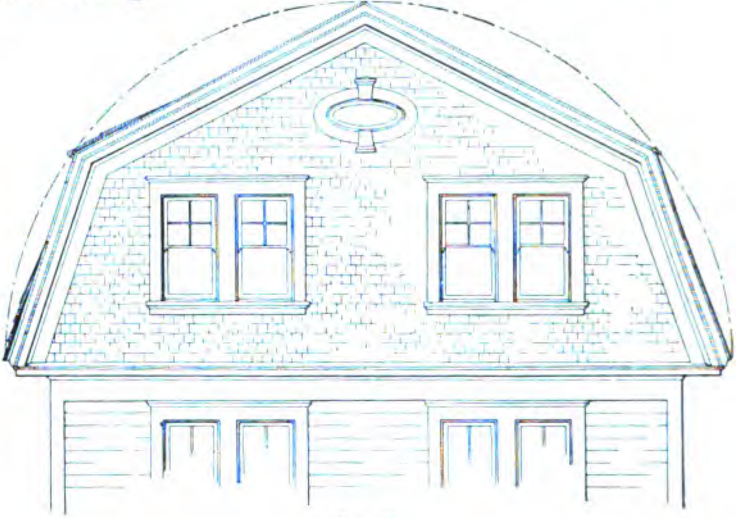


Fig. 15

18. Mansard Roofs.—The **Mansard roof,** sometimes called a *curb roof*, is shown in Fig. 16, and, as will be seen, it resembles the gambrel roof in having a very flat top *a b c d* and very steep sides *a d f e* and *d e g f*. The points of difference, however, are equally prominent; for, while the ends of a gambrel roof are always enclosed with gables, the Mansard roof is always the same on all sides, therein somewhat resembling the hip roof.

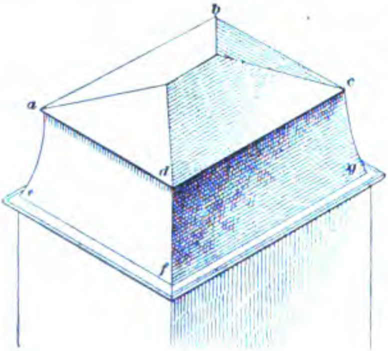


Fig. 16

The sides of the Mansard roof are generally, though not always, curved, and are much more nearly perpendicular than the sides of the gambrel roof, as, in reality, these lower slopes of the Mansard are nothing more than continuations of the side walls of the building. In fact, the distinguishing characteristics between the gambrel and the Mansard roofs may be said to be that the former is an endeavor to make the inside of the roof appear like an upper story, while the latter is an effort to make the outside of the upper story look like part of the roof. From the fact that the wings of large buildings, called *pavilions*, are often covered with this form of roof, the Mansard roof is sometimes termed a *pavilion roof*.

The relative pitch of the top and side slopes of a Mansard roof may be determined in several ways, one of which, known as Belidor's method, is shown in Fig. 13. Variations from this rule are common in practice, but these proportions are such as will usually give most satisfactory structural results.

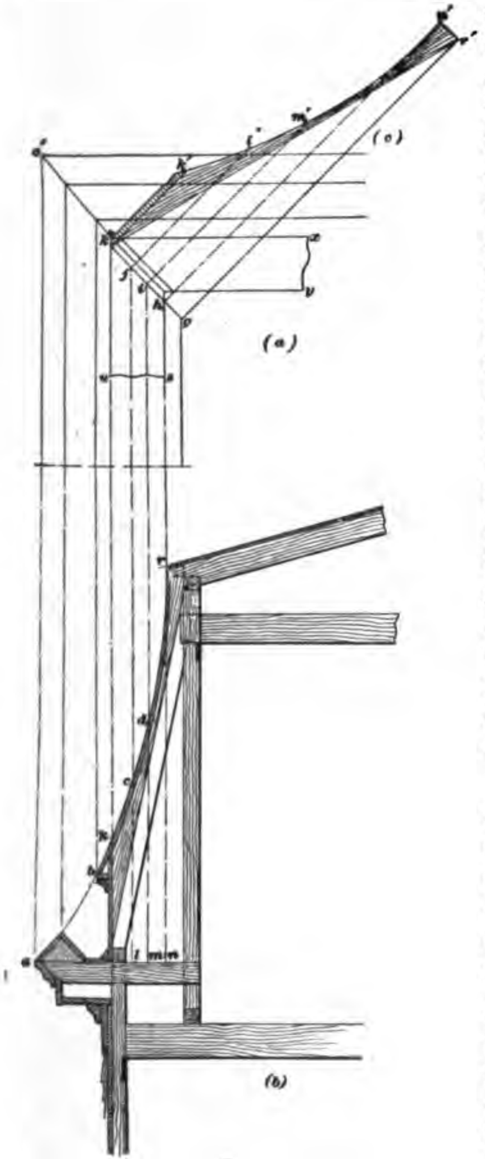


FIG. 17

19. In Fig. 17 is shown a plan (*a*) and a section (*b*) through the lower slope of a Mansard roof, while at (*c*) is shown an elevation of the angle rib at *ae* or *df*, Fig. 16. In the plan (*a*), $uk''x$ is a corner, or angle, of the building at the lowest portion of the sloping sides of the roof, and is designated in the section (*b*) by *k*. The line *shy* in the plan is the upper edge of the sloping side and is designated in the section by *r*. If now, in the section, any number of points, such as *c*, *d*, *r*, are projected up from the curved side, and their intersections with the line $k''g$ are marked at *j*, *i*, *h*, and from these points and at right angles to $k''g$ the lines jl', im', hn' are laid off equal to *cl*, *dm*, and *rn* in the section, points l', m', n' in the curve of the angle rib will be obtained, and these points, if connected by a curved line, will give the profile sought.

The distance $k''k'$ on the angle rib (*c*) is the height of the point *k* in the section above the bottom of the main slope at *a*.

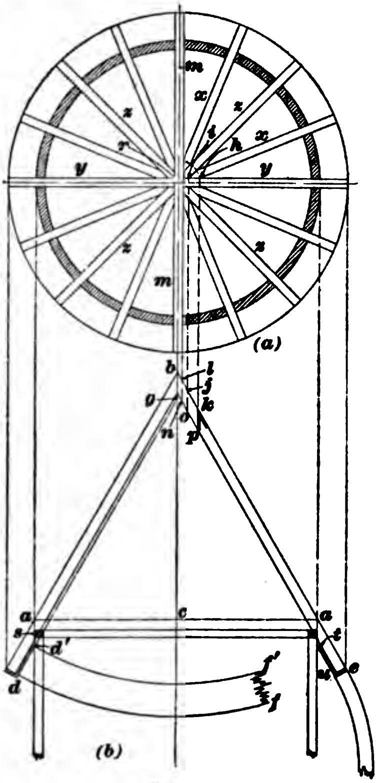


FIG. 18

20. Conical Roofs.—In Fig. 18 is a framing plan (*a*) and sectional elevation (*b*) of a **conical roof**, the height of which is *cb* and the pitch *ba*. The rafters *ab* are notched over the plate in the same manner as though the roof were a plain gable, but the mitering of the upper ends is somewhat different, and can be best understood by referring to the plan (*a*).

The first pair of rafters *m*, *m* have a plumb-cut exactly the same as a gable rafter and are butted squarely together at *r*, while the second pair *y* are similarly cut and butted and spiked at their upper ends against the first pair. The rafters *z* are then cut the same as *y*, but with the addition of a cheek cut at an angle of 45° on both sides of the upper end; and the rafters *x* are made similar to *z*, except the cheek cuts are each 22½°, instead of 45°.

In the elevation *b*, the rafters are shown overhanging the plate from *a* to *e* in order to form the eaves, and the length *e b* will be the length of the two rafters shown in the plan at *m*. From *b c* is then measured off, at right angles, the half thickness of the rafter *m*, and through the point thus located, a perpendicular line is drawn, cutting the rafter at *n l*; *e l* will then be the length of the rafters shown in the plan at *y*. The point *i*, where the edge of the rafter *z* intersects the edge of the rafter *y*, if projected down to the elevation (*b*) will cut the elevation of the rafter at *o j*, and *j e* will then be the length to the cheek cut of the rafters shown in the plan at *z*. The length of the rafters *x* to the cheek cut is then found by projecting the points of intersection of adjacent sides of *x* and *y* to the top of the rafter in elevation, cutting the rafter at *p k*; *k e* will then be the length of the rafters to the cheek cut, as shown in the plan at *h*. The angle *e k p* will be the plumb-cut for all the rafters in the roof. See Arts. **62** and **63**.

21. The wall plate, shown in the elevation at *s*, Fig. 18, is cut out of two thicknesses of 2-inch plank, each piece being long enough to receive the feet of four rafters. When the plate is built in position, it is laid up in two thicknesses, no two joints of which are to be in line perpendicularly, and the joints on the under side should be well supported by studs.

The under side of the rafters, where they project beyond the plate, is sometimes lined, or sheathed, with a board *t u* called the *plancher*, or soffit, and the ends of the rafters at *e u* are then faced with a board called the *fascia*. The proper curvature of the edges of the plancher *d f* is found by drawing the line *dg* parallel with the inside of the rafter and at a distance from it equal to the thickness of the plancher; this line will intersect the axis *b c* of the roof at *g*. Then, with *g* as a center and radii *g d* and *g d'*, describe the arcs *d f* and *d' f'*, which will give the curvature required. The length of the plancher on the line *d f* will, of course, be equal to the circumference of the roof at *d*.

22. Where a conical roof intersects the pitch of another roof, it is necessary to resort to particular framing in each case. Fig. 19 shows the plan of a conical-tower roof *a b c d* intersecting a flat single slope *e f h g*, the line of intersection being the curve *a d c*.

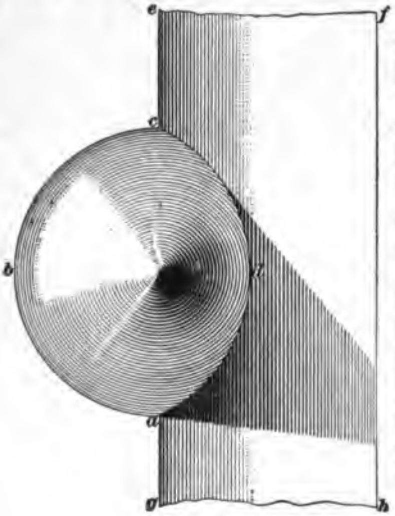


FIG. 19

In Fig. 20, the plan (*a*) of the tower is divided into sixteen equal parts by the radial lines *y' a'*, *y' x'*, *y' b'*, etc., each one of which represents the center line of a rafter. The sectional elevation (*b*) shows the apex of the roof at *y* and the rafters and their slopes at *y b* and *y d*, while *d b* is the line of the plate. The rafter *v p* shows the slope of the main roof to which it belongs, and the point *w* shows the highest point in the line of intersection between the conical tower and the main roof.

If the lines *y x*, *y t*, *y z*, etc. are drawn to points *x*, *t*, and *z*, the projections of the points *x'* in the plan, these lines will indicate the position of the tower rafters in the elevation; where these lines intersect the main-roof slope at *s* will be points in the curved line of intersection between the two roofs.

Projecting the points *s* on each rafter to the plan of each rafter at (*a*) will give the points *s'*, which are all in the line of intersection between the two roofs, as shown at *a d c*, Fig. 19, and through which the line of intersection *a′ s′ c′*, Fig. 20, can be drawn. Horizontal lines drawn from the points of intersection *s* to the outside of the rafter, or slope line, *y d*, will give the length *y g* of each of the rafters *y s*.

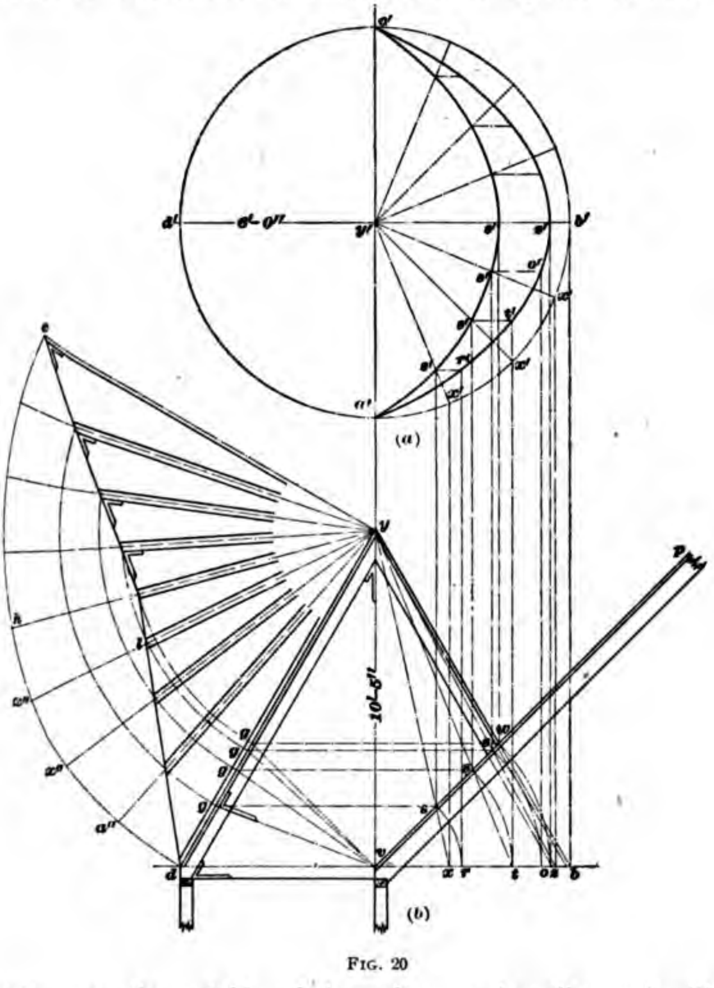


FIG. 20

The plumb-cuts at *y* and the foot-cuts at *d* are similar to those shown in Fig. 18, but the foot-cuts of the rafters, where they rest on the surface of the roof *vp*, are found in the following manner: With *y* as a center and a radius *yd*, draw the arc *dhe*, on which space off the feet of the rafters, as at a'', x'', x'', etc., and to these points draw radial lines from *y*. Make *yj* equal to *yw* the length of the shortest rafter, and draw *je* and *jd*; then, the angle that *je* or *jd* makes with the foot of each rafter will be the cheek cut of that rafter on the roof, and a line *gv* drawn from the foot of each rafter *yg* will give the angle *ygv*, which is the bevel of the foot-cut of each rafter as it rests on the roof *vp*.

The line of intersection between the two roofs, as shown in the elevation at *vw*, is seen in the plan (*a*) at $a' s' c'$, and being at an inclination, does not exhibit the exact curvature as it would appear if seen in a horizontal position. The points in the line of the true curve may be found in the following manner: With *v* as a center and with radii *vs*, describe the arcs *sr*, *st*, *so*, etc., and where these arcs intersect the line *db* erect the perpendiculars rr', tt', oo', etc. From the points s' in the plan draw the horizontal lines $s' r'$, $s' t'$, $s' o'$, etc., and where these intersect the perpendiculars just described will be the points in the curve required, through which points the true curve $a' r' t' o' z' c'$ may be described.

The advantage of finding this curve is that from it a paper templet may be made with the points $a' r' t' o'$, etc. located on it. With this templet, the curve may be marked out on the boards of the roof *vp*, and the rafters of the conical roof footed on the points $r' t' o'$, etc. with great exactness.

Where the tower roof *dyb* is of large size and is liable to throw considerable weight on the main roof *vp*, short pieces of timber should be framed in between each of a pair of rafters where one of the tower rafters is to set its foot. On small towers, the boarding of the roof is usually of sufficient strength in itself and requires no timbers inserted beneath it.

23. Hexagonal Roofs.—A hexagonal roof and the system of framing it is shown in plan in Fig. 21, where the six hip rafters radiate from the center *o* to the corners of the hexagon *h f b g*, etc. The two pair of rafters *c o j* and *g o h* should be set in place first, as in the conical tower, Fig. 18, and the other hip rafters are then fitted against them. To find the plumb-cut and foot-cut for these hip rafters, lay off ***o a*** equal to the height of the roof and join *a* and *b*; then, the angle *o b a* is the bevel of the foot-cut, and the angle *o a b*, the bevel of the plumb-cut, while the distance *a b* is the length of the hip rafter.

The middle rafters *o j*, *o a*, *o c*, etc. are found by laying off the height of the roof at *o d* and joining *d* and *c*; then the angle *o c d* is the foot-cut and the angle *o d c* is the plumb-cut on the rafters *o j*, *o a*, *o c*, etc., and their length is equal to the distance *d c*.

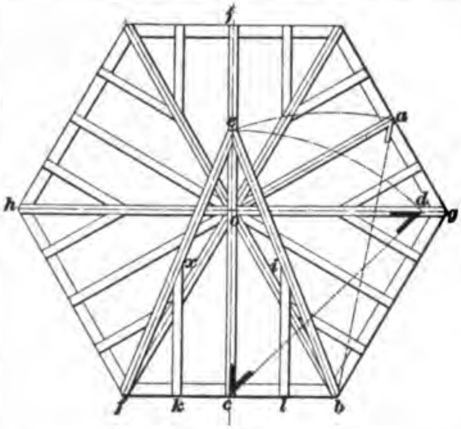


FIG. 21

If now, from *b*, ***b e*** is laid off equal to ***b a***, the length of the hip rafters, and the lines *e b* and *e f* are drawn—on each of which, as a center line, the thickness of the rafter is laid off—the jack-rafters *k x* and *l i* can be drawn in. Then, the angle *f x k* will be the bevel of the cheek cut, and the angle *o d c* will be the angle of their plumb-cut, which is similar to that of the rafter *o c*, to which the jack-rafters are parallel. See Arts. **62** and **63** on Spire Construction.

24. Bell and Ogee Roofs.—Sometimes, a tower or other small structure is covered with a roof, the outline of which is composed of curved lines instead of the usual flat slope. This curved outline is usually compound in form; that is, one end is convex and the other is concave. When such a sloped roof is put on a circular tower, it is called a **bell roof,** on account of its resemblance to the shape of a bell; but when applied to a square or polygonal tower, it is called an **ogee roof**, from the fact of its outlines being of an *ogee*, or double-curved, shape.

25. In Fig. 22 is shown a plan (*a*) and a sectional elevation (*b*) of the ogee roof of a square tower. The ribs, or rafters, *a t* and *t b*, shown in the plan (*a*), are either sawed or bent to the required shape, fitted squarely together at the top, and fastened in place. The ribs at *f′ t* and *g′ t* are next fitted, but are each shorter in length than the former pair by half the thickness of *a t* or *t b*. The hip ribs *l t*, *m t*, *r t*, and *q t* are now put in place, and finally the jack-rafters *o h*.

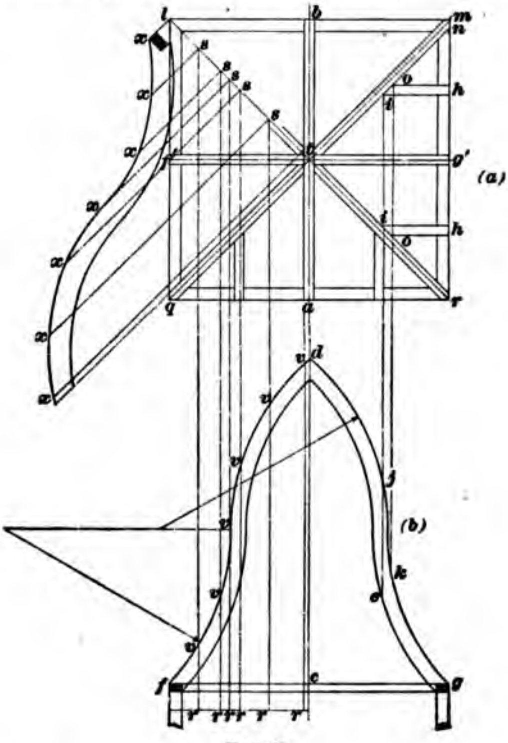


FIG. 22

To determine the length and curve of the hip ribs, or rafters. *l t*, *q t*, etc., draw *t x* at right angles to *l t* and equal in length to the height of the roof cd; divide the rib fd into any number of parts, by making points as at v, and from these points erect perpendicular lines vs parallel with dc. Where these lines intersect lt at s, draw the lines sx at right angles to lt, making sx in each case equal to the corresponding lines rv in the elevation (b). Through the points x draw the curve xxx, which will be the profile of the angle rib required.

The length of the jack-rafters oh is found by dropping perpendiculars ok and ij from each side of their cheek cuts parallel with cd and intersecting dg at k and j. Then, jg will be the extreme length and proper curve of the jack-rafters, while their plumb-cut will be on the line je. The cheek cut of these jack-rafters is found by drawing a line from j on the outside of the rafter to k on the inside, which is shown in the plan (a) by the line io. The hip rafters lt, mt, etc. must have their upper edges beveled on each side of the center line, as shown in the plan at mn. This is done in order that the boarding of the roof may have an even bearing on the angle rib. The edges of the boarding must meet accurately on the center line of the rib mt. The amount of bevel required on the angle rib is found by drawing a line parallel with the upper edge and at a distance mn below this edge by means of a scratch gauge;

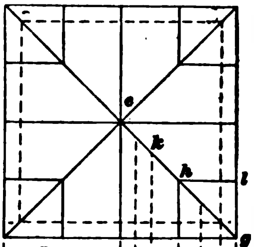


FIG. 23

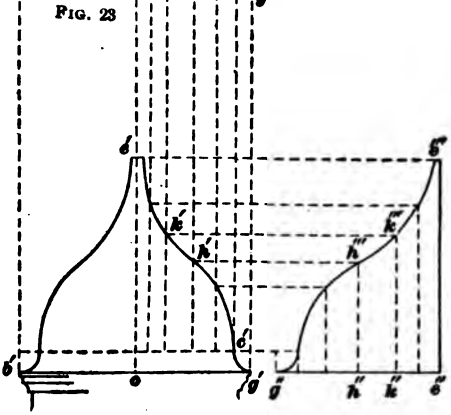


FIG. 24

the wood between this line and the center of the top of the rafter is then cut away.

26. Profiling Hip and Jack-Rafters for a Curvilinear Roof.—In Fig. 23 the arrangement of the rafters is shown in plan, eg being a hip rafter and hl a jack-rafter. In Fig. 24, the elevation $b'g'$ is the span and oe' the rise. To find the shape of the hip rafter eg, make $e''g''$ equal in length to eg, and lay off $e''k''$, $k''h''$, etc., equal to ek, kh, etc. Erect perpendiculars at e'', k'', h'', etc. At e, k, h, etc., drop perpendiculars cutting the curve $e'g'$ at k', h', etc. From e', k', h', etc. draw horizontals cutting perpendiculars from e'', k'', h'', etc. at the points e''', k''', h''', etc. A curve drawn through these points gives the required outline of the hip rafter. The shape of the jack-rafter hl is the same as the curve $h'g'$.

DETAILS OF ROOF CONSTRUCTION

27. Cornice and Gutter.—In building the roof of a house, the rafters are nearly always carried beyond the front of the plate from 10 to 24 inches, or more, in order that the drip from the eaves may fall clear of the wall of the house. Fig. 25 shows the method of cutting the rafters where they so project, and also a method of finishing and enclosing the rafters and of forming a standing gutter.

A rafter $abefdc$ is notched over the plate g at cd and projects beyond the plate at df. The portion of the rafter below cd is cut away to lighten the appearance of the eaves. At h is a tie-beam, which is spiked to the ends of the rafter on each side of the building, and in this case also forms the ceiling beam of the upper story and rests on the plate g. From the top of the tie the rafter is closely boarded with 1-inch boards k, the lower one of which is allowed to project about half its width beyond the end of the rafter at ei. The end of the rafter is cut on the line ef, which is parallel to the plumb-cut at the ridge, and the soffit, or plancher, j on the bottom of the rafters has its outer edge beveled to the same angle, as has also the top of the fascia l, which finishes the ends of the rafters. A crown molding *m* is then secured in place by nailing it to both the projecting roof board *k* and the front of the fascia *l*. This gives a finish to the projecting eaves, and the under side is completed by the insertion of the molding *o* between the soffit *j* and the frieze, or top casing, *n*. This finish is usually called a *box cornice*, in that it is formed by a boxing, or casing, of wood. Over the roofing boards, and outside the line of the front of the building, a bedplate *p* is nailed securely to each rafter, to form the gutter, as will be explained further on.

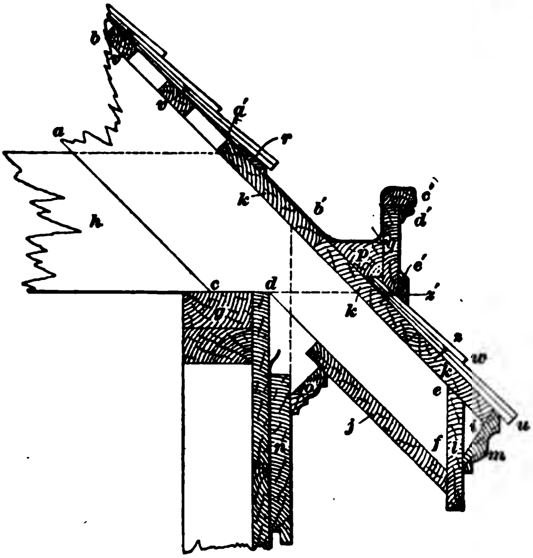


FIG. 25

Four other forms of box gutters are shown in Figs. 26, 27, 28, and 29; the gutters shown in Figs. 26, 27, and 28 are for frame buildings and that in Fig. 29 for a brick building. Fig. 28 shows a gutter formed of sheet metal running well up under the shingles and over the crown molding of the cornice itself. This gutter stands entirely free above the surface of the roof and is braced every 3 feet by metal straps, as shown.

28. Roof Covering.—Roofs are variously covered with wooden shingles, steel shingles, slate, tin, lead, zinc, corrugated iron, copper, or tiles. A flat roof should always be covered with tin, copper, or other material that is practically one piece, as water will run back between the joints of shingles, slates, or tiles, and thereby get into the interior of the building. A pitched roof may be covered with any of the materials mentioned, but shingles, slate, or tiles are generally used.

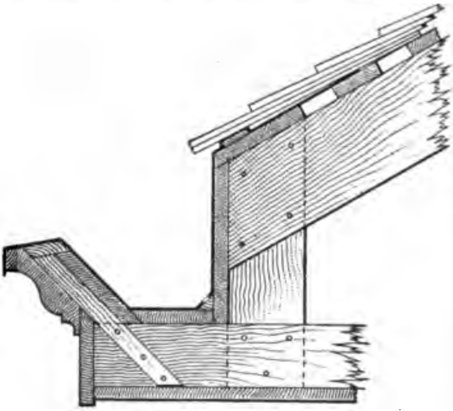


FIG. 26

29. Shingling.—Shingles are laid on the roof of the house, either on sheathing boards, as shown at *k*, Fig. 25, or on shingle laths, as shown at *v*. The latter method is preferable, as it gives better ventilation to the under side of the shingles and prevents the accumulation of moisture at that place. When boards are used as a roof covering on which shingles are to be laid, they should not be laid close, as at *k*, except over the eaves. **Under no conditions should paper be placed under shingles.**

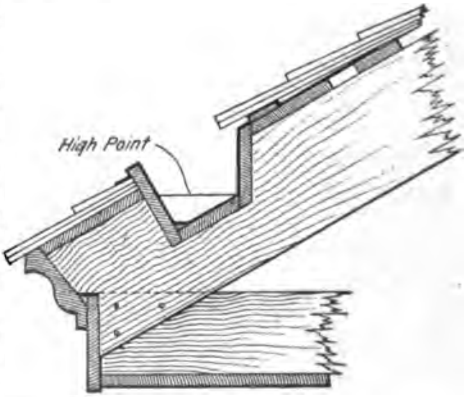


FIG. 27

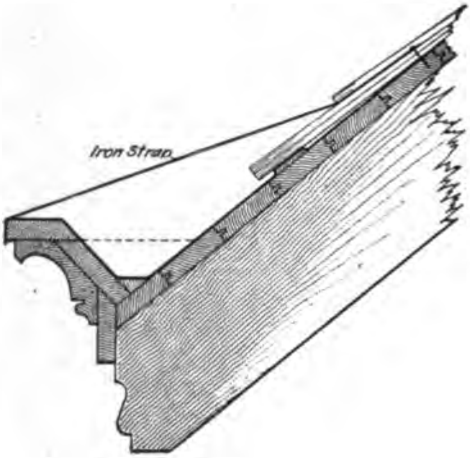


FIG. 28

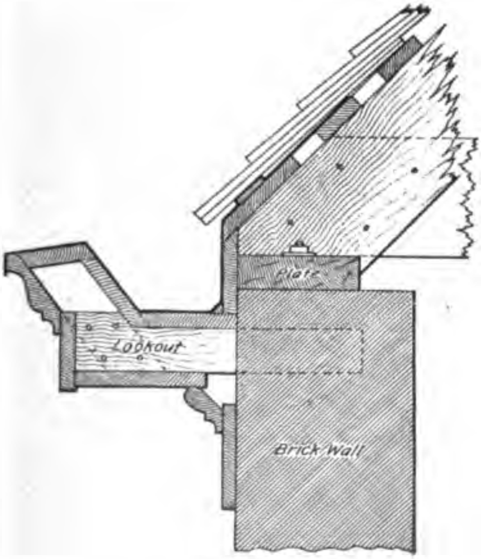


FIG. 29

Shingle laths, shown at *v*, are usually 1¼ in. × 2 in. or 1¼ in. × 3 in., and are laid at right angles to the rafters and from 4 to 8 inches on centers, according to the exposure of the shingles to the weather. The amount of this exposure also determines the length of shingles that can be used with the greatest economy of material consistent with first-class work.

Shingles vary in length, and can usually be obtained in regular sizes of 16, 18, and 24 inches in length, and from 4 to 7 inches in width. The size to be used in each case should be about 3 inches longer than three times the length exposed to the weather.

The first course of shingles is placed at the eaves, being laid double with broken joints, as at *u*, Fig. 25, in order that water finding its way through the joints of the upper layer may not readily percolate through the lower layer and rot the roofing boards, fascia, etc.

When the first course is laid, each shingle is nailed with two nails about 2 inches above the upper line of its exposure; the amount of exposure is then measured back from the lower, or butt, edge of the shingles, and a line is struck by means of a chalked cord, to which line the butts of the next course are laid, as at *w*. This protects the nails driven into the previous shingles by the 2-inch lap shown at *z w*, and the nails of the second course also pass through the upper ends of the first course, as at *z'*.

30. After the shingling is completed up to the gutter plate *p*—which, in this case, requires but two courses—the gutter face board *q* with its lower edge beveled to fit the top of the shingles is set in place. A plinth *e'*, a cap member *c'*, and bed mold *d'*, may now be nailed in place.

In lining the gutter with copper or tin, a strip of hoop iron should be nailed along the edge of the cap *c'*, allowing the lower edge to project below the cap. To this edge the metallic lining may be clasped, from which point it extends across the bed of the gutter to *b'* and up as far as *a'*. It is well to have the metallic lining extend 5 or 6 inches under the shingles. When the first course of shingles above the gutter is laid, the course is doubled for the same reason that it is at the eaves. As these shingles are the lowest on the roof, they get the most water and are therefore more liable to rot. To prevent this, a tilting strip is placed as shown at *r*. This fillet raises the shingles off the roof and allows the air to circulate better under them, thus facilitating the drying out after a rainstorm. The remainder of the roof from here up to the ridge is shingled, one course at a time, as already explained.

31. Gutter Lining and Leader Pipes.—The lining of a gutter should be of the best quality of material, with all the joints properly folded, if of tin, and well soldered. The lining should also be painted on both sides and well fitted to the gutter. The gutter plate *p*, Fig. 25, is made of a varying width so that the gutter has a gradual pitch toward the *leader*, or outflow, pipe, which is located at the lower end. This leader is usually made of tin, corrugated galvanized-iron, or copper pipe from 2 to 6 inches in diameter, according to the size of roof from which it must carry the water. Where the area of a roof is very great, more than one leader may be necessary to carry off the accumulation of water during a heavy rain. A liberal allowance is to provide 1 square inch of leader section for each 75 square feet of roof area; but never to use a leader less than 2 inches in diameter. Even that size is liable to become choked and clogged with dirt or leaves in a wooded section of country, and should be used only for veranda, porch, bay-window, and other small roofs.

The leader is inserted through the bottom of the gutter and its metallic lining, and must be well soldered to the latter, while its *throat*, or inlet, should be countersunk, and protected with an open iron grating or wire screen, to prevent foreign substances from entering with the water.

32. Flashing.—**Flashing** is a term given to all sheet-metal work used in connection with roof covering to insure a water-tight condition at joints and angles. Flashings are required on hips, valleys, ridges, and eaves, around scuttles, skylights, gables, flanks of dormer-windows, etc.

33. On hip roofs, where angle rolls are not used, pieces of flashing are laid on the hip over each course of shingles or slate in the same manner that a shingle or a slate itself would be laid, if it could be bent to fit around a corner as shown at *a*, Fig. 30. For, while the joints between the various pieces of roof covering may be broken, or alternated, as at *b*, in the main flat slopes, the hips must have a continuous row of joints from the eaves to the ridge, as at *c*, and the insertion of flashings under the shingles at these points prevents the water that would work its way beneath the covering from getting into the interior, and carries this water to the flat slopes, where it may run off harmlessly.

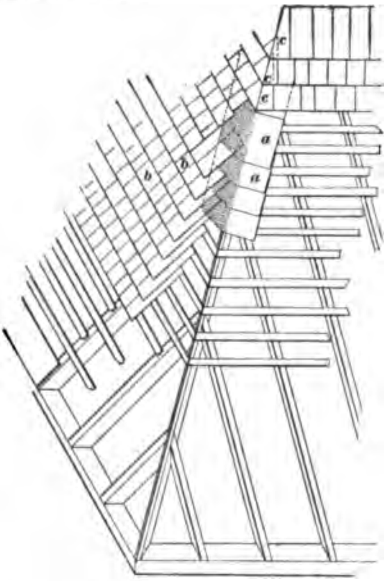


Fig. 30

34. In valleys, the means adopted are different, as the conditions are in some respects reversed. On the hip of the roof there is no accumulation of water at any time, and what little may fall there is immediately drained off by the pitch; but in the valley there is a depression between two slopes, and all the water falling on each of them is immediately carried to the valley.

The valley, therefore, acts in the capacity of a gutter, and is flashed accordingly. The tin is joined, generally at the ends, to form a continuous gutter in the depression, and its edges are turned up about 6 inches under the shingles. The shingling is not carried down to the intersection of the slopes, but is stopped about 5 inches from the valley rafter, and the gutter is thereby left open. The flashing of all such situations will be treated in detail in *Sheet-Metal Work*.

35. Along the ridge, the roof is rendered water-tight by a number of methods, two of which are illustrated in Figs. 31 and 32. In Fig. 31 is shown a method used on a shingle roof that requires no flashing, while in Fig. 32 a metal flashing is used on a slate or flat-tile roof. In Fig. 31, the ridge plate *a* is carried above the line of the shingle lath *b* and the top of the shingles *d*, and its top is beveled off to conform with the general pitch of the roof. After the shingling is complete, the top of the ridge is finished off to form a continuation of the top surface of the last course of shingles, and the *ridge boards c* are nailed to it and to each other in the position shown.

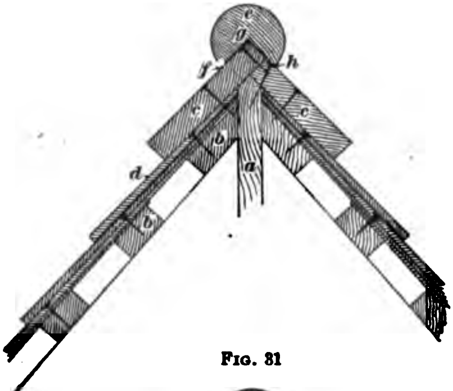


Fig. 31

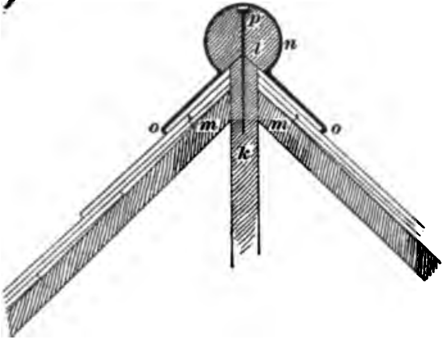


Fig. 32

Before the ridge boards are nailed in place, there should be a layer of two-ply roofing felt folded over the ridge, on top of which the ridge boards may be firmly nailed; this will assist in making a thoroughly water-tight job. These ridge boards are usually from 1 inch to 1⅛ inches in thickness, and from 5½ to 9 inches in width, according to the amount the shingles are exposed to the weather.

The *ridge roll e* is formed from a single piece of wood, is from 2½ to 3 inches in diameter, and is rebated, or rabbeted, at *f g h* to fit the angle at the top of the ridge boards. This V-shaped groove, or rabbet, should be deep enough to permit the edge of the roll *h* to lap well over the joint between the two ridge boards *c*.

In Fig. 32, the slating of the roof *m* is carried up to the beveled end of the ridge plate *k*, butting against it as the shingles do in Fig. 31, and the wooden ridge roll *l* is rabbeted over the joints formed at the ridge. This roll is held in place by long spikes *p* driven through its top into the upper edge of the ridge plate, and over it is sprung the galvanized-iron covering *n*, which has been previously shaped to fit the roll and catch the under edge of the last course of slates, as at *o*.

Ridges, like hips, are very slightly subject to leakage, and, as little water falls on them and practically none remains after it has fallen, the same precautions are not required with flashings at these points as would be necessary elsewhere.

36. Around skylights and dormer-windows, where the sill rests on the slope of the roof, flashing is applied so that it extends under the roof covering, adjacent to the sill and turns up and over the sill itself in such a manner as will prevent any possibility of water entering between the sill and the slate or shingles. The sides of a dormer, where they intersect with the roof pitch, are flashed in the same manner as are the valleys, except that the shingling or other covering may be carried up close to the finished sides.

37. **Precautions to be Observed in Roofing.**—Great care must be observed along the eaves of a roof, especially where that roof is over a well-heated room, as the interior heat during the winter will cause the snow on the roof to melt and run to the eaves, where, relieved from the effects of the high temperature, it freezes and builds up a dam of ice, and the accumulated water backs under the shingles and gets into the house. Under these conditions, it is sometimes desirable to build the gutter above the line of the plate, in order that the same heat that melts the snow may sufficiently

warm the gutter to prevent it from freezing up when its services are most needed.

Unless the pitch of a roof is at least 45° above the horizontal, there is much danger of leakage during windy weather, as a high wind will drive the water under the shingles and through the first crevice that presents itself—hence the importance of exercising the greatest care with all the flashings, and of securing broken joints in each course of shingles.

Shingles with loose knots or open knot holes within half their length of the butt, or shingles that are split, or shaky and liable to split, should be rejected. Rejected shingles should be broken or cut through with a hatchet, lest some other workman, with less precaution, be inclined to use them. The slight apparent waste thus caused is nothing compared with the expense and inconvenience of a leaky roof.

DORMER-WINDOWS

38. Dormer-windows, a term applied to windows projecting from the roof of a building, are framed out when the roof is constructed. The size and the shape of the openings left for them between the rafters depend on the size and the character of their roofs.

Where the walls of a building are carried about half a story above the attic floor line, the upper portion of the dormer-window will project above the eave line as shown in Fig. 33. In this manner very desirable rooms are obtained in the attic by reason of the extra wall height. The general appearance of the roof mass is also pleasing on account of the broken eave line, and the effect of the lean-to roof over the dormer suggests that the roof has just been raised to accommodate the window. Such windows look best in roofs of high pitch, as the roof over the dormer will still have a reasonable pitch in itself. The eaves of the main roof in this case are shown finished with metal hanging gutters.

39. In Fig. 34 is shown a low, picturesque dormer well adapted for cottage work; this dormer is perched on the

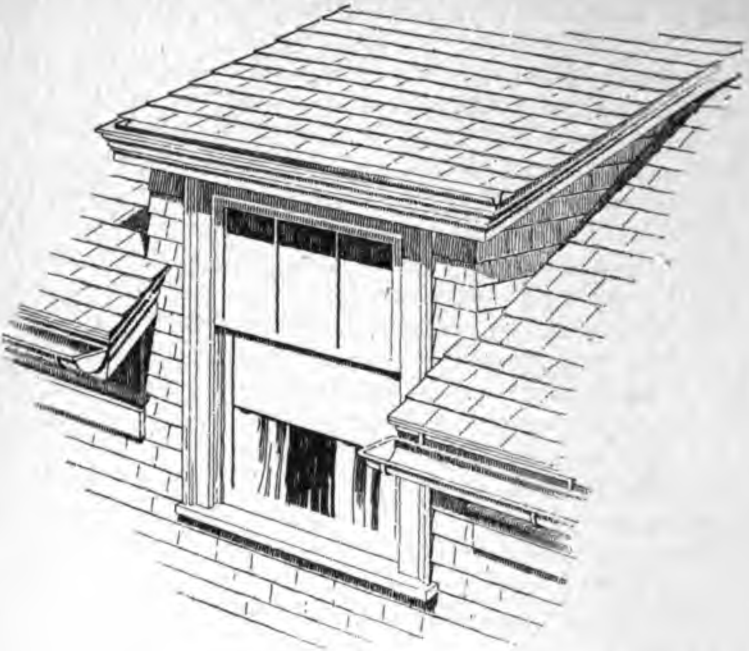


Fig. 33

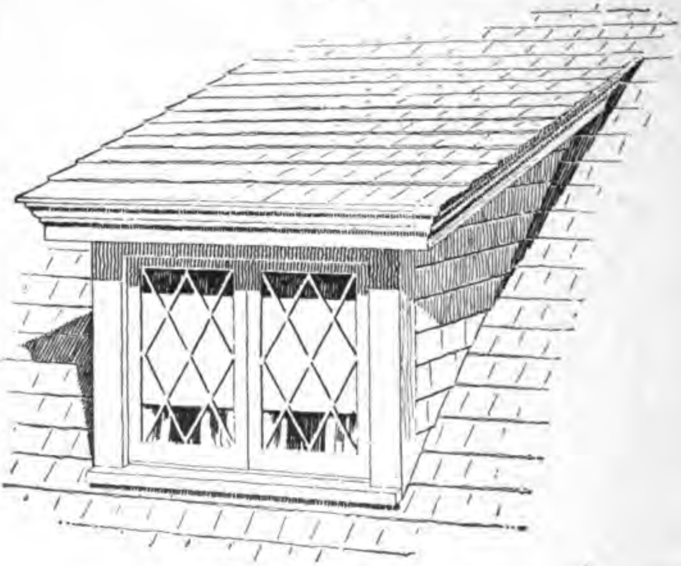


Fig. 34

slope of the main roof, the treatment of the roof being similar to that in Fig. 33. The sashes in this instance are *casement-hung*, which implies that they are hinged on the jambs and fold like a door. They are made to open either out or in, but are tighter when made to open out. The subdivision of the lights *lozengewise* adds to the quaintness and is suggestive of the days of our grandfathers.

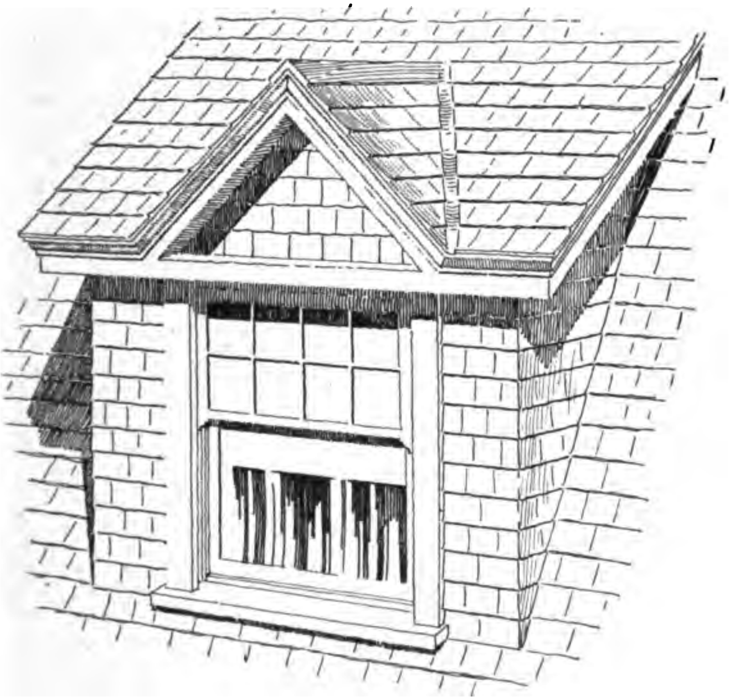


FIG. 35

40. Where a good width is desired in the interior of the room adjacent to the window, a portion of the wall may be continued beyond the window casing, as shown in Fig. 35. The eave line of the dormer, which, in this example, would be somewhat long, is broken by a gablet, or pediment, thus relieving the horizontal depression and giving the window the effect of greater height. It will be seen that the main roof is quite steep, suggestive of the pitch of a gambrel roof, and thus a good pitch is obtained for the roof of the dormer proper.

41. Fig. 36 shows a dormer whose width is restricted to that of the casing of the window frame. This dormer has a roof with a double pitch and a hip end. The cornice is carried around horizontally, while the hips are finished with what are known as *Boston hips*, the method of putting them on being explained in *Roofing*.

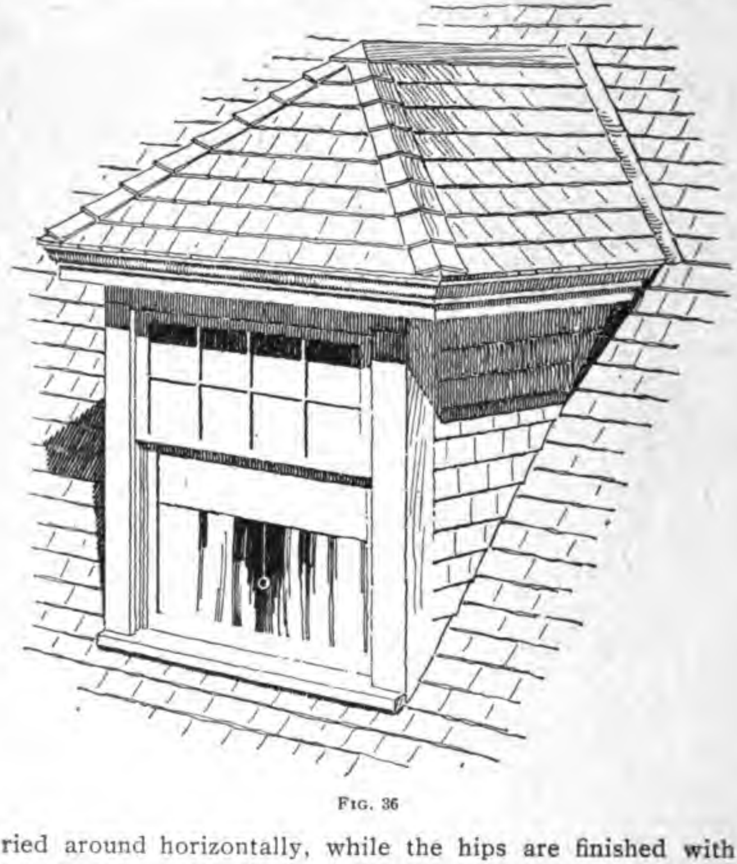


Fig. 36

This is a very desirable style of dormer, and when well proportioned and detailed always looks well. In this form of dormer roof, the pitches of the front and sides should be the same as that of main roof, unless such a window is inserted in a gambrel or Mansard roof, in which case the pitch would be made to suit the taste of the designer and the effect desired.

42. In Fig. 37, the dormer is finished with a pediment. The corona, or fascia, is carried around horizontally. The cymatium, or crown mold, on the eave is carried up the rake, thus making it continuous; but it has a somewhat different contour than the horizontal member, so that it may miter properly at *a*, and is called a rake mold. Sometimes, the full cornice of the eaves is carried across the front with the pediment surmounting it, but owing to the heavy, overloaded

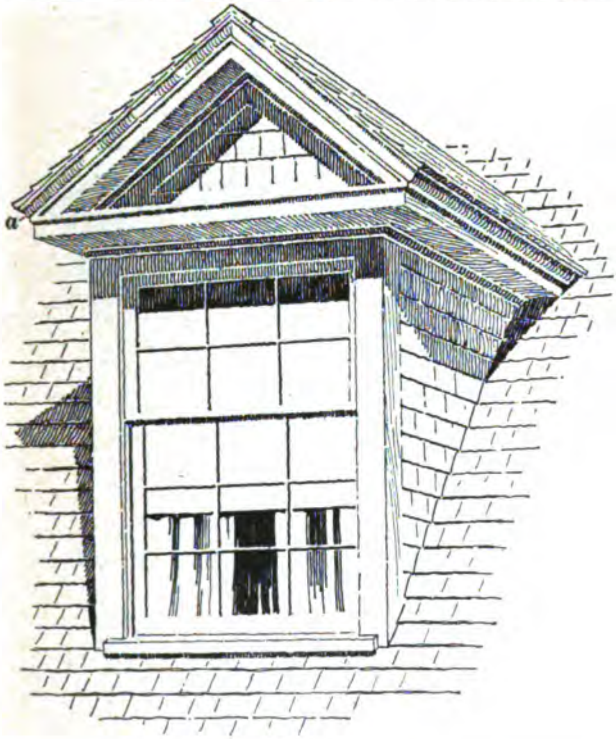


FIG. 37

appearance that it gives, the method is objectionable and should never be followed. The pediment gives the dormer more prominence, and has a tendency to subordinate the main roof, unless it is very high. For cottage work, the hipped end gives more of a sense of repose to the roof and subordinates the dormer to the main roof, of which it is a part.

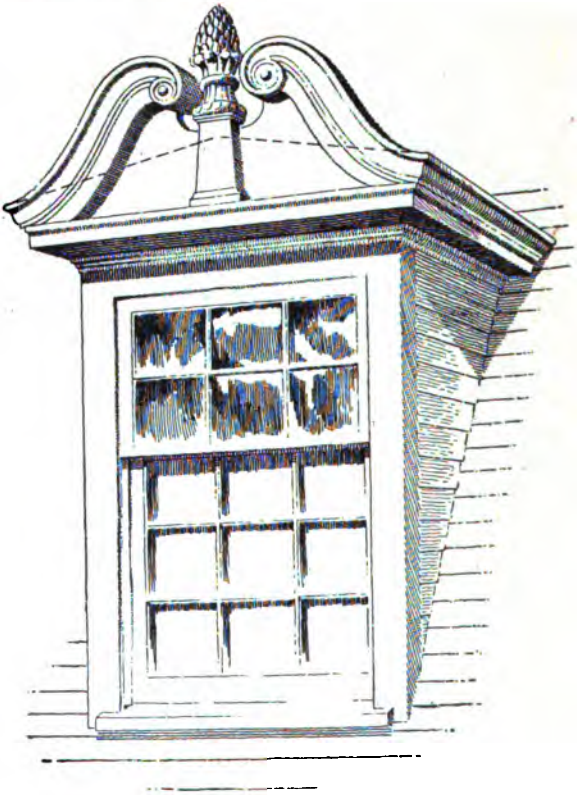


FIG. 38

43. A similar dormer is shown in Fig. 38, but is finished with what is called a *broken pediment*, in that the pitches of the cornice are broken and do not come together at the ridge, while the outline of the pediment is curved. Only a portion of the roof about 8 inches in width and directly over the curved cornice, would conform therewith, as the balance of the roof would be a low-pitched one, falling behind and below the 8-inch parapet just described, as indicated by the dotted lines. The roof covering, owing to the flat pitch, would be of metal, either tin or copper.

The effect of such a treatment of a pediment, while graceful and pleasing, and relieving the roof from the severe angular lines of the roof pitches, is condemned by many designers, in that it is constructed ornament and not ornamented construction. The form of the roof is not structurally suggestive of one designed to shed water, but rather to hold it, and in this sense violates good design. Others, however, prefer to violate this principle, on the ground that the good effect justifies it, and offset their sin by calling it "artistic license."

It will be observed that all the foregoing examples have their *flanks*, or return walls, shingled or slated. The construction of these walls is similar to that of the walls of a balloon-framed building. The junction of the flank and roof covering is laid close, the angle being made water-tight by concealed lap flashings of metal, laced in with each course of shingles or slates as the case may be.

44. A **wagon-head dormer** is shown in Fig. 39. This style was much used in colonial times, and, unlike the previous example, it is structurally correct in design. Owing, however, to the lack of an eaves line well defined by a cornice, and practically no frontal projection other than the curved architrave, this dormer lacks the sense of cover and protection, which is the cardinal principle in well-studied roof design. As is obvious, the roof and flanks are covered with metal. This covering may be laid flat like an ordinary tin roof; or, the surface may be divided by 2″ × 2″ metal-covered ribs, set about 14 inches on centers, or by standing seams, which will take away the flat and uninteresting appearance of the continuous roof and flank, as indicated in the figure. Where judgment is used in placing this style of dormer in buildings whose keynote is structural simplicity, and when properly proportioned to the roof proper, favorable results in appearance are obtained. Complying with the spirit of its antecedents, the sash bars are made twice as thick as usual, that is, from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in thickness, thus giving an increased body to the window as a whole.

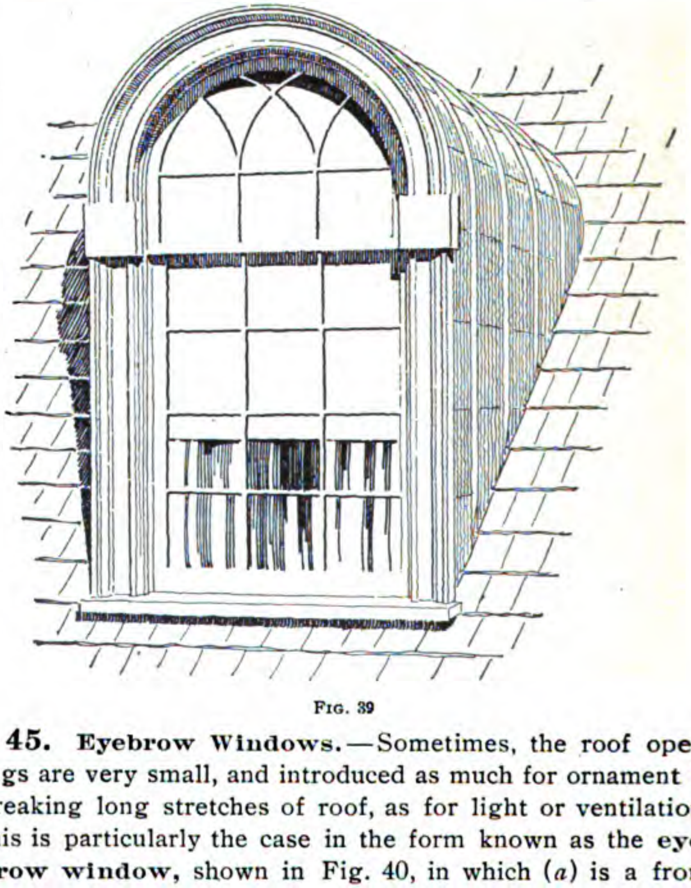


FIG. 39

45. Eyebrow Windows.—Sometimes, the roof openings are very small, and introduced as much for ornament in breaking long stretches of roof, as for light or ventilation; this is particularly the case in the form known as the **eyebrow window,** shown in Fig. 40, in which (*a*) is a front elevation and (*b*) a sectional side elevation through the center of the roof. The dotted lines *b'*, *c'*, *d'*, etc. of this section show the curvature of each of the ribs *b*, *c*, *d*, etc. of the front elevation.

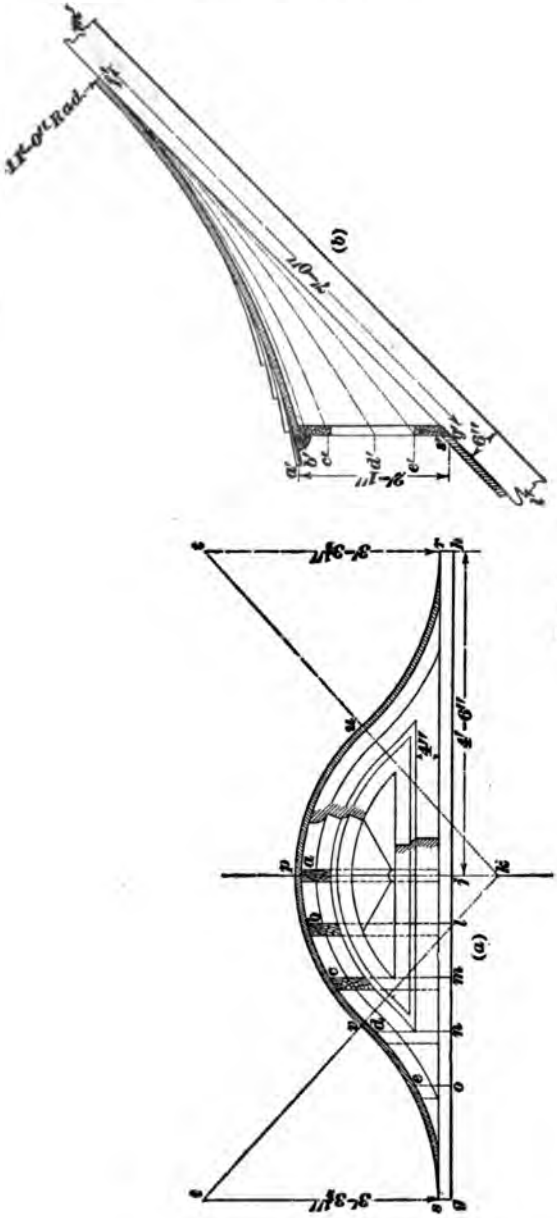
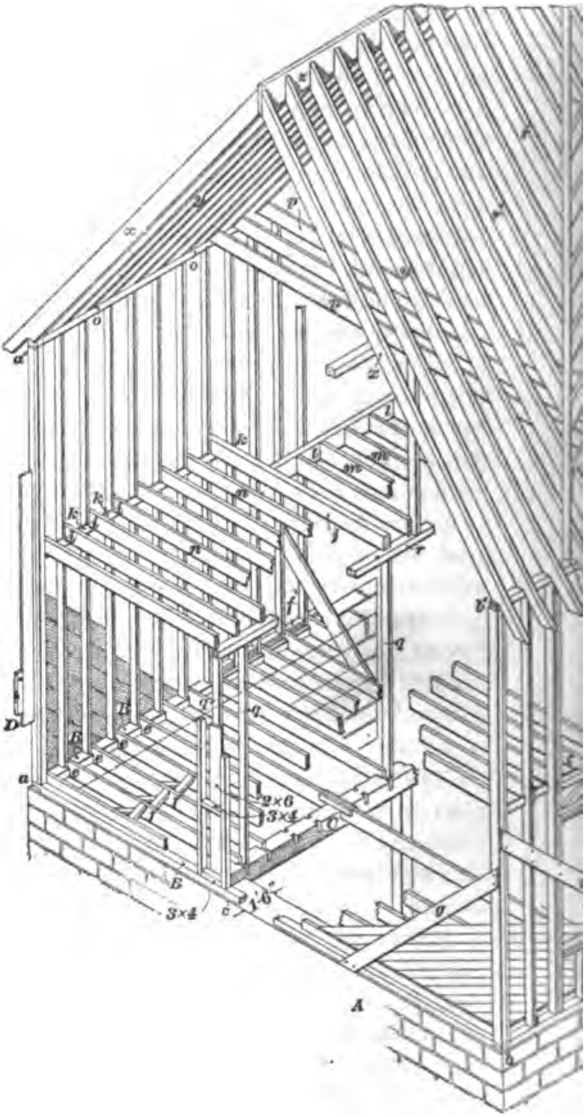


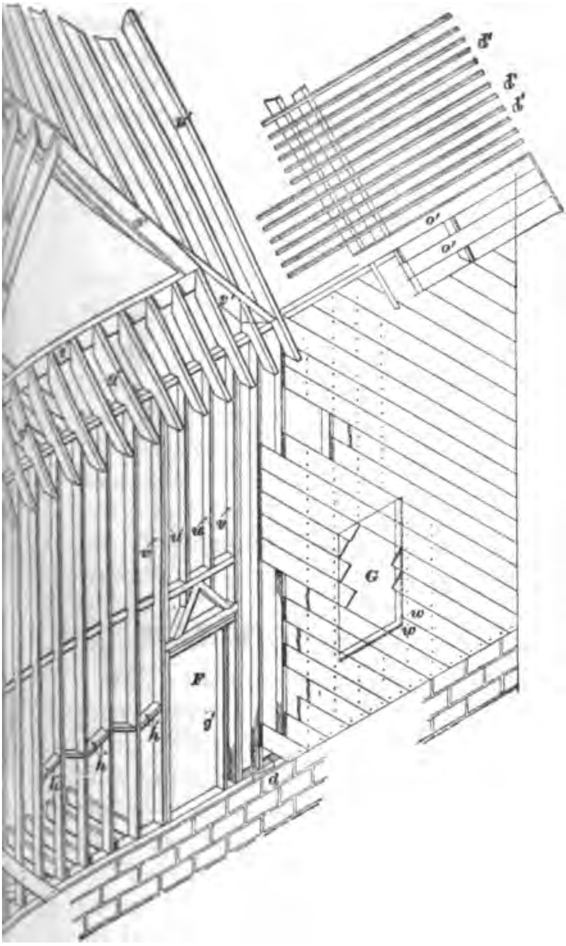
FIG. 40

The example shown in Fig. 40 is 9 feet in length from *g* to *h*; the line *gh* is the top line of the main rafters, as shown at *g′*, while the line *sr* is the top line of the roof sheathing, as shown at *s′*. The height *jp* is 2 feet, and the curve of the front elevation of the roof *spr* is formed with three arcs of circles, the centers *t*, *t*, and *k* of which are located in the following manner: Prolong the center line *pj*, and with some point *k* as a center, describe the arc *upv* with such a radius that the points *u* and *v*, where this arc intersects the lines *pr* and *ps*, will fall below *p* less than half the distance *pj*. Then, from *k*, the center of the arc just mentioned, draw the lines *kt* through the points *u* and *v*, and the points *t*, *t* where these lines intersect *rt* and *st*, drawn perpendicular to *sr*, will be the centers for the arcs *ur* and *vs*, which complete the compound curve of the top of the window. All the curved parts of the elevation are described from these centers, the arcs above the lines *kt* being described from *k* as a center, and those falling below the lines *kt* being turned on *t*, *t* as centers. The ribs, or rafters, *a*, *b*, *c*, *d*, and *e* are now spaced off to stand about 9 inches on centers, and, as will be observed, the top and bottom edges will be beveled to conform more closely to the curved outline of the roof, except the middle rib *a*, which is, practically, rectangular in section.

In the section through the center of the window shown in (*b*), *a′*, *b′*, *c′*, *d′*, and *e′* are the ends of the ribs, shown at *a*, *b*, *c*, *d*, and *e* in the front elevation (*a*), and the lines *f′a′*, *f′b′*, etc. are the tops of these ribs and the profiles of their curvatures. The rafter *l′m′* shows the pitch of the main roof, and the roof of the eyebrow window curves upwards toward this rafter and becomes tangent at *f′*. All the ribs *a′f′*, *b′f′*, *c′f′*, etc. become tangent at *f′*, and the bevels of their top and bottom sides, shown in the front elevation (*a*), gradually diminish as they recede, until they are all rectangular in section. The curvature of the ribs, as shown by the dotted lines *f′c′*, *f′d′*, etc., is determined by striking the curve of the uppermost rib with the arc of a circle, the radius of which must be perpendicular to the rafter *l′m′* at *f′*, and the distances *g′e′*, *g′d′*, *g′c′*, etc. are laid off to correspond



155 F



§ 32

with *oe*, *nd*, *mc*, etc. in the front elevation. From each of the points *e'*, *d'*, *c'*, etc. is then drawn the top line of the rib to *f'*, varying the curvature in each successive rib to such a degree as will keep them the same relative distances below one another as at their starting points *a'*, *b'*, *c'*, etc. The ribs are sawed out of 2-inch plank on lines developed as just described, and the shingle laths are bent over the curve and continued on the main roof without interruption, as the curved outline of the window removes all necessity of valleys, and, consequently, of flashing.

When the roof is shingled, the lines of the shingle butts are carried along over the eyebrow window, so that, in reality, it forms simply a protuberance of the main roof.

46. Windows of the same general character as the eyebrow window are sometimes constructed with a flat, square roof, curving upwards slightly as it recedes toward the main roof, so that its section is similar in shape to Fig. 40 (*b*). The ribs forming the roof construction, however, are all alike and rest on a straight plate in front, while the sides are shingled, or sheathed, in the same manner as a dormer-window.

BALLOON-FRAME CONSTRUCTION

47. **Balloon framing,** as heretofore explained, is the term given to that system of construction in which the skeleton, or framework, of a building is spiked together with butt joints, and depends almost entirely for its strength and stability on its exterior covering and the manner in which this covering is applied.

The construction of a balloon-frame building will now be taken up. Such methods and means as have already been set forth will be applied, and such new or additional features as the necessity or the economy of the construction demands will be considered as they appear.

48. In Fig. 41, *A* is a stone foundation wall, 1 ft. 6 in. in thickness. On top of the foundation wall is spread a bed of lime mortar at *c*, in which the sill *B* is laid and well bedded by means of repeated blows from a heavy hammer. When this is done, the outside edge of the sill, which is kept back 1 inch from the face of the wall, is pointed up; that is, the joint between the sill and the top of the wall is carefully scraped off to give it a neat, even finish, and any surplus mortar is removed from the 1-inch projection of wall. The plate is halved and spiked at the corners as shown at *a* and *b*, and where the pieces composing it cannot be obtained in sufficient lengths, the sill is pieced out by means of the beveled splice, as shown at *d*. In exposed situations where high winds are frequent, it is not uncommon to anchor the sill to the wall by means of anchor bolts. These bolts are from 1 inch to 1½ inches in diameter, and are firmly built into the masonwork of the wall with the thread end projecting above it. Holes are then bored into the sill to fit over these projecting ends, and, after the sill is laid and leveled, it is securely held in place by screwing nuts tight on the ends of the bolts with a washer between each nut and the sill.

49. After the sill is set in its place, leveled, and its angles squared so as to be absolutely true, the first tier of floorbeams may be laid. These floorbeams are notched over the sill to bring their tops to a level line; or, where great economy of material is to be desired, the beams are notched 4 inches or more to bring their under sides about flush with the bottom of the sill, where they are bedded in the same mortar topping of the foundation that the sill itself is, or the beams are blocked up on top of the wall with pieces of slate. But in all cases where they are so deeply notched the floorbeams must have a solid bearing on the wall, as shown at *e*, Fig. 41.

Where the span is so great that the beams must have an intermediate support, a brick wall, or a girder supported on posts, as shown at *C*, is carried through the center of the house. A brick wall is better for the purpose than a girder, for, when built up to the same height as the foundation walls and capped with a wooden sill of the same thickness as the main sill, there will be the same amount of shrinkable material in all the supports of the first-story beams and partitions. Where a girder is used, however, precautions must be taken to equalize, as nearly as possible, the effect of its shrinkage with that of the main sill. This is done by notching the girder, as shown, and by notching the beams in the same manner as at the sill, so that the solid portion of the girder below the notches is equal in thickness to the depth of the main sill of the house.

Great care is required in cutting these joints, so as to insure a good seat, not only for the beam on the bottom of the notch, but also for the projecting tenon of the beam on the top of the girder; too much weight on the notch would tend to split the girder, while too great a strain on the tenon would tend to split the beam. It is for this reason that in strictly first-class work the beams are simply sized over the main sill, and their inner ends are similarly sized over an interior sill supported on a brick or stone wall.

Whether they meet on a girder or wall, the ends of the beams should be butted together and held by cleats nailed on each side; they should never be lapped one beam on the side of the other and spiked together, as this produces irregularity in the beam spacing, and makes the subsequent laying of hot-air pipes, etc. very troublesome. The floorbeams having been spaced and securely nailed along sill and girder at the uniform distance of 12 or 16 inches on centers, are then cross-bridged, as shown at *f*.

50. While this bridging is in progress, or even before it is commenced, the side walls of the building are started by setting the corner posts *a a'* and *b b'* in position. After these posts have been carefully plumbed with a level and straightedge, as shown at *D*, or preferably by a long plumb-rule and plumb-bob, they are braced in position by two pieces of sheathing nailed securely to the posts and to the sill, as shown at *g*.

The corner posts are generally composed of two pieces spiked together, as shown at *b b'*, Fig. 41, and the larger piece is sometimes, though not always, mortised or doweled into the sill.

51. After the corner posts are secured, the studs are spaced along the sill 16 inches on centers and are spiked both to the sill and to the floorbeams. These studs are then plumbed and carefully alined along the outside edge of the sill, and secured in place with braces similar to those of the corner post, those on the exterior being permanent in the form of sheathing, while the brace extending from the side of the stud to the floorbeam is but a temporary affair, to be removed as soon as the interior partitions and the second-story beams are in place.

These studs and corner posts are all cut to an even length on the ground before they are set in place, and at the same time the notches for the ledger boards *k* are cut in the studs 4 inches wide and 1 inch deep. As soon as the studs are set in place, the ledger board itself is fitted and spiked to each stud with two nails.

On this ledger board the floorbeams *n* of the second story are laid, each beam being slightly notched on its under side, as at *i*, in order to bring the tops of the beams to an even alinement. The second-story beams are not nailed to the ledger board, but are securely spiked to each stud, on the same side of the stud as the beams in the tier below.

52. The beam shown at *j* is double the thickness of those at *n*, as it is a trimmer beam and carries the header *l* and the weight from the tail-beams *m*. This header and trimmer form one end of the stair well, or opening, and if there is to be a similar opening in the third, or attic, floor, great care must be taken to place the attic-floor header perfectly parallel with and plumb over this one, as trouble will arise when the stairs are built unless such care is observed.

53. As soon as the second-story beams are laid, the tier above may be started, but if this third tier is simply to consist of ceiling beams, and the attic story is not to be finished off in rooms like the rest of the house, the wall plate *o* should be laid first. This plate is usually composed of two pieces of studding nailed together and so lapped that the joints of any two lengths are as far apart as possible, and is laid along the top of the wall and securely nailed to each stud. The attic beams are then notched over the plate in the same manner that the first tier of beams was notched on the sill, and securely nailed in place.

The exterior frame is now fairly complete from sill to plate. While the work just described was in progress, the partitions were erected, the first, or rough, floors laid on the interior, and the window and door openings framed and the frame sheathed on the exterior. In fact, it is sometimes necessary to erect the main partitions at the same time as the outside walls, in order to provide a support for the interior ends of the floorbeams.

54. The studs *q*, *q* supporting the partition plate *r* show the position of a principal partition supporting the ends of the second-story beams *m* and *n*, and the continuation of this partition in the second story supports the interior ends of the attic beams *p*.

The plate *r* on the top of these stud partitions, like the main wall plate *o*, is generally composed of two pieces of studding nailed together, and though one thickness would be strong enough for all practical purposes, the two pieces are preferable in order to secure the same amount of shrinkable material under each end of the beam; and, as the ledger boards on the outside are 4 inches deep, the plate in the interior is also made 4 inches deep.

55. The framing of the openings is shown at *E*, where the studs on each side of the opening are doubled and spiked securely together to act as practically one piece. The head and the sill of the opening, if it is a window, are also composed of doubled studs, and where the window is over 3 feet in width, the top should be trussed. The double studs at the sides of the opening are carried through to the plate, and if there are to be two openings, one over the other, it is simply necessary to truss the upper one, unless there are floorbeams or other details that will concentrate too much weight over the opening. This is the case at *E*, and the window head is trussed to carry the load of the two beams *t* to the double studs at the sides.

56. In laying out the studding of the exterior walls of a building, two methods are used, one where the double studs at the sides of the doors or windows are first placed in position, and the single intermediate studs are spaced 16 inches on centers between them; and the other method, in which the studs are spaced throughout at the uniform distance of 16 inches on centers, after which the door and window openings are sawed out and the studding framed to suit.

The former of these methods is shown at *E* and the latter at *F*, where two studs *u* have been cut out and the adjacent ones *v* have been doubled, the space between them being trussed to carry the floorbeams in the same manner as at *E*. This leaves an opening of 4 feet between the centers of the studs at the sides of the opening, and, as this is more than is required, the opening is limited by the stud g' cut in between the truss and the sill; or, if the plan requires the door to be further to the right, two studs can be cut in and the opening centered at any point desired.

57. Sheathing is composed of $\frac{7}{8}$-inch boards, matched or unmatched, and planed on one side to give them a uniform thickness. In balloon-frame buildings, the sheathing should always be laid diagonally, as it is on the bracing effect of the diagonal sheathing that the building depends for its strength. The sheathing is then carried over the whole side of the building, no attention being paid to door or window openings, except where a sheathing board projects a few inches over an opening; it is permitted to remain so, and the next board to it in the course is started from the other side of the window.

This arrangement is illustrated at *G*, where the dotted lines show the outlines of the window opening, and the full lines indicate the sheathing boards as they are laid up on the studs, to each one of which they are nailed with two tenpenny nails. At *w* is shown the sheathing sawed out to the opening, the boards being cut flush with the face of the studs.

58. When the sheathing is nearly completed and the first, or rough, floors are laid, the structure is ready to receive the first timbers of the roof.

The pitch of the roof in this case is rather steep, being 17 inches rise to 12 inches run. The plumb-cut of the rafters will be found by laying a steel square on the side of the timber with 17 inches of the blade and 12 inches of the tongue on the line of what is to be the top edge of the rafter; the outside line of the blade will then mark the plumb-cut. The foot-cut and overhang for the eaves are measured and cut, and when one rafter is finished and sawed complete, it is used as a templet for marking and cutting all the others, before the framing of the roof is commenced.

The first rafters set are those forming the end of the gable at *x*. The ridge plate *z* is composed of a wide piece of 1⅛-inch material beveled on its upper edge, as previously explained. To this ridge plate the rafters *x* are spiked on opposite sides, and somewhere near the other end two other rafters are similarly spiked to hold the ridge plate in position. The rafters *y* and *y′* are so placed as to foot on the plate *o* adjacent to the valley rafters *w′* and *v′*, which are then placed in position, having been previously cut to the required lengths. The valley rafter *w′* is first set, and then the valley rafter *v′* is securely footed on the plate and spiked against it. The header plate *t′* is then spiked between these two valleys at the point where the slope of the smaller gable is to start, and after *t′* is securely nailed to the two valley rafters, the first two of the small gable rafters *s′* may be set in position, securely nailed to the header plate *t′*, and spiked through the ridge plate *u′*, the other end of which is nailed into the angle formed between the two valley rafters *w′* and *v′*.

The ridge plates *z* and *u′* and the header rafter *t′* must, of course, be perfectly true and level, and when set they must be so securely fastened that subsequent operations will not force them out of line. The jack-rafters *r′* and *p′* may now be set in pairs, one each side of the valley rafter *w′*. This is done in order that the thrust may be the same on each side of the rafter at the same time, for, if all the jack-rafters were laid on one side at the same time, it would cause the valley rafter to bulge and curve out of line and prevent the opposite rafters from fitting properly.

For this same reason great care must be exercised in setting the jack-rafters *q'*, as, in driving them close into their places, the header rafter *t'* is liable to be bulged inwards and out of line with the gable rafters *s'* above.

59. After all the rafters are in place, the boarding of the eaves is laid, as shown at *o'*, and above this boarding the shingle laths *d'* are laid, with a clear space between them equal to the exposed length of the shingles. The spacing of the shingle laths is measured from the lower edge of the lowest roof board at the eaves, and the spaces are measured off up the rafters to the ridge, where any difference in exposure of shingles can be taken up either by increasing or by slightly diminishing the width of the ridge boards when they are laid. Side sheathing, roof sheathing, and shingle laths must be nailed to each stud, or rafter, using two nails for boards and one nail for shingle laths. Where a joint occurs in a length of board or shingle lath, it must be in the center of the rafter, or stud, and both joining ends must be securely nailed to the supporting timber.

60. The rough framing of the building may now be considered as complete. The skeleton is up and covered with its sheathing; the floorbeams, or joists, are in position, and the rough, diagonal flooring is laid; the partitions dividing the interior are all studded, and the openings for doors and windows have all been framed and sawed out through the sheathing.

It now remains for the carpenter to lath the partitions, cross-fur and lath the ceilings, nail on the grounds that are to secure the wainscot, trim, picture moldings, etc. on the inside of the building, and to set the frames for the windows and doors, apply the outside casings, put on the clapboards, or siding, and shingle the roof on the exterior of the building; his work will then be practically complete, until after

the joiner and painter have finished. In many localities, the lathing is done either by special lathers or by plasterers.

61. Before the walls are lathed, it is sometimes desirable, in buildings where the ceilings are high, to provide a line of bridging between the studs, as shown at *h'*. The bridging tends to make the walls stiffer sidewise, and the studs are thus prevented from warping.

At *f'* is shown a filling of *brick nogs*, as they are called, from the top of the foundation wall to the top of the beams. This nogging consists of pieces of old or broken bricks laid in lime mortar so as to completely fill the spaces between the studs and up to the top of the beams, thus not only closing a passageway for cold drafts from the cellar, but also preventing the rapid spread of flames in case of fire. The brick nogging may, with advantage, be continued up three courses higher than the beams, between the studs, which will prevent drafts at the floor level, caused by the circulation of the air through the channels between the studding. Sometimes, where brick is not convenient, short pieces of 2″ × 4″ studs are filled in and spiked to the sill and beams.

SPIRE CONSTRUCTION

62. Angular Spires.—One of the most important points in construction is that of proper anchorage. This requires more consideration than usual in the case of a spire, owing to the fact that it is subjected to high wind pressures, which affect its equilibrium. In Fig. 42 is shown the framing and anchorage of an octagonal spire.

While the long, tilted rafters, usually spliced to attain extreme heights, are in compression on one side, they are in tension on the other. This is due to horizontal wind pressure, which has a tendency to tip over or raise one side of the base, with an opposite side acting as a fulcrum. To obviate this, the rafters, as shown at *m*, Fig. 42 (*a*), are bolted to the plate *n*, which in turn is bolted to vertical timbers *l* in the four internal angles of the masonry. These timbers rest on and are strapped to the girders at r and are bolted at s to iron plates t, which are embedded in the walls below. This arrangement, together with its intermediate bracing, would make it necessary to dislodge two stories of masonry before the spire would give way. Fig. 42 (b) shows a plan at the plate line taken through $v\,v$ in (a); (c) shows a half plan at $w\,w$; (d) is taken at $x\,x$; (e), at $y\,y$; and (f), at $z\,z$. The bolts o are 1 inch in diameter; p, $1\frac{1}{4}$ inches; q, $1\frac{1}{2}$ inches; and s is a $1\frac{3}{4}$-inch rod.

Although many other forms of construction are in use, they are all based on the same general principles as given in this example.

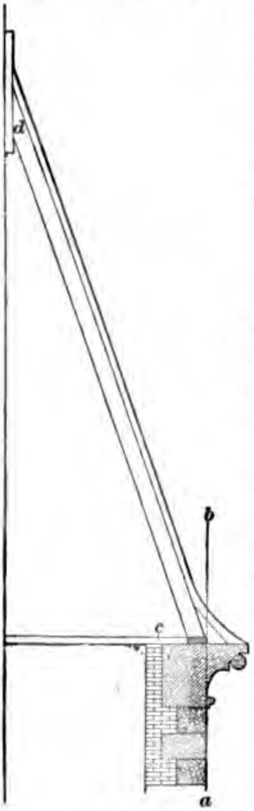


FIG. 43

63. Conical Spires.—Prominent features of city and suburban architecture are presented in the circular towers and the semicircular bay windows finished above the main roof as towers. The wall angles of public buildings are often ornamented with small towers terminating in spires, which form a pleasing characteristic in the design. It is to be regretted, however, that want of study and lack of attention to detail cause the roofs of many of these towers to have the appearance of "candle extinguishers."

The elements requiring consideration are the proper proportion of height to diameter, the relative value of the tower roof to the main roof, and the placing of the rafters with due reference to the eaves line. The unevenness of the finished roof is another defect, and is usually produced by using sheathing boards of too great width. This causes the vertical lines, where the sheathing boards abut, to be visible after the shingling or slating has been applied. The same effect may be seen in tile roofs, but is somewhat obscured by using tiles that present only vertical rolls placed at close intervals.

The width of the sheathing should be so regulated that the arc included between the edges of the boards will be, as near as practicable, a straight line. If the bell cast is such that extra-thick material is required to secure the desired curvature, the staves may be made up of two or more pieces in the length. Conical roofs with a bell cast at the eaves are characteristic of French architecture. The tower roofs of the

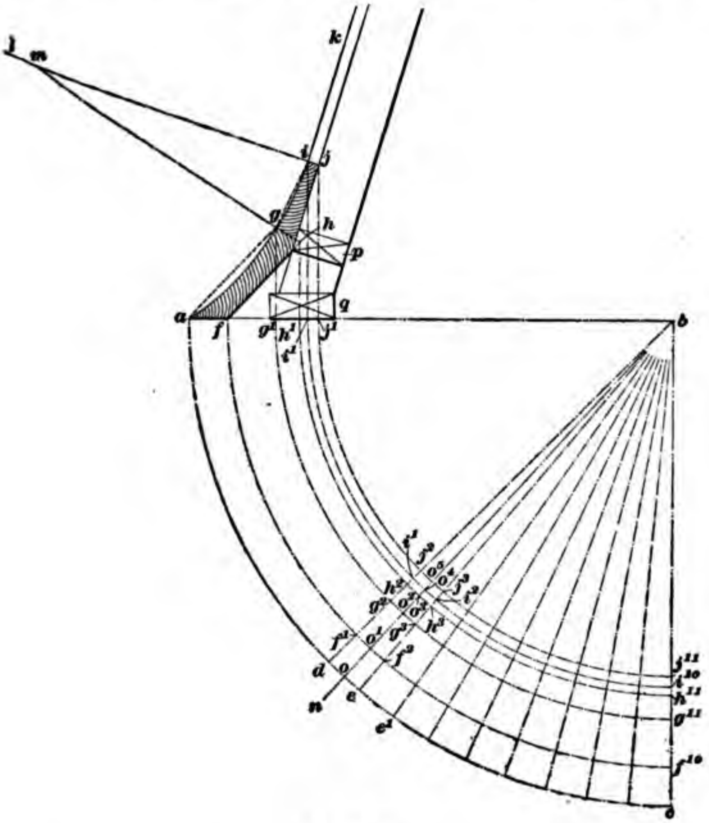


FIG. 44

Château Martinville, the Château de Vitre, and the Château Chenonceaux are striking examples. They are, whether by accident or design, very successful; they are graceful in outline, and their surface is smooth and continuous.

The trades, as a rule, use the method whereby the work can be executed with the least amount of material and with the greatest despatch, without giving a thought as to the durability and ultimate effect. This is especially so where the work is sublet, and where each contractor considers himself independent of the others. Thus the task of covering up and trying to improve the poor work of a predecessor generally devolves on a trade foreign to the necessities of the case.

64. A fixed rule for the height of tower roofs would not be desirable, as the opinions of designers vary, but a safe course to follow is to have a low-pitched tower roof when the main roof is low, and to have a steeper one when the main roof has a greater pitch, thereby producing a feeling of unity in the design.

A rational rule to follow in placing the rafters is to continue the constructive lines, and never let the toe of the rafter project beyond the plate line, or face, of the tower wall.

When the cornice is in position, the space between the crown molding and the toes of the rafters may be utilized for a gutter, or preferably a *bell cast*, flare, or curved continuation of the roof slope. In Fig. 43 is shown the proper position of the rafters, *a b* representing the wall line, *c* the wall plate, and *c d* the roof rafter so set that the toe is on the line *a b*.

65. To obtain the proper horizontal and vertical mitering for the curved sheathing, when the pitch of the roof and the curve of the bell cast are given, the following method may be used: Lay out one-quarter of the plan of the tower, as in Fig. 44, as indicated by the quadrant *a b c*; divide the arc *a c* into two equal parts, and draw *b d*; divide the arc *d c* into any desired number of spaces, as indicated at *e*, *e*^{1}, etc., denoting the width of the sheathing, or staves, at their base.

The surfaces contained in $afgh$ and $ghij$, with a face width equal to de, represent the smallest material out of which the staves may be cut. At the junction of the straight slope of the roof ik and the bell cast agi, draw the line il at right angles to ik; and, as the arc ai is tangent to ik, the upper miter cut will be the extension of il at j.

On the line il, at the given point of radius m, describe the arc ai. Divide the arc ai, as at g; from the center m draw the line mh through the point g; then, gh will be the horizontal miter cut for the foot of the stave $ghij$, and the upper horizontal miter cut for the stave $afgh$.

To obtain the vertical-side miter cuts, project the points g, h, i, and j to the horizontal line a, b, cutting it at the points g^1, h^1, i^1, and j^1. With b as a center, describe the quadrants ff^{10}, g^1g^{11}, h^1h^{11}, i^1i^{10}, and j^1j^{11}. From b draw the line bn through the center of a stave, as at o.

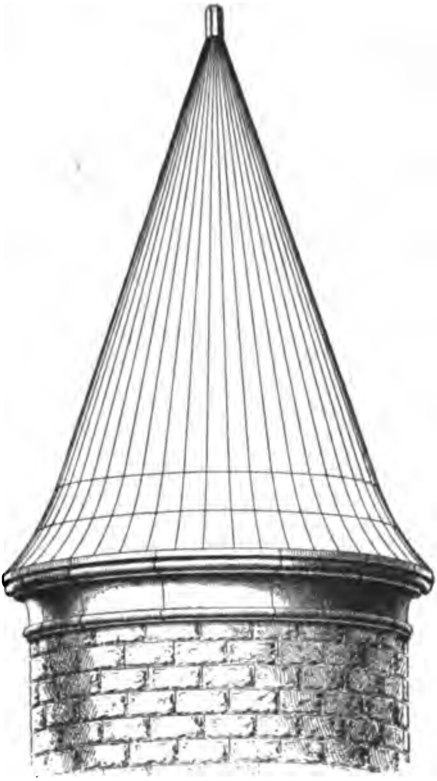


FIG. 45

66. In laying out the stave, set off on the face of the lower one, at its base, the ordinates od, oe, and at its top the ordinates o^2g^2, o^2g^3. Set off on the under side of the stave, at its base, the ordinates o^1f^1, o^1f^2, and at its head the ordinates o^3h^2, o^3h^3. Draw bd through $f^1g^2h^2$, and be through $f^2g^3h^3$, giving the vertical side miter cuts of the lower stave.

Set off on the face of the upper stave, at its base, the ordinates $o^2 g^1$, $o^2 g^2$, and at its head the ordinates $o^4 i^1$, $o^4 i^2$.

Set off on the under side of the stave, at its base, the ordinates $o^3 h^1$, $o^3 h^2$, and at its head the ordinates $o^5 j^1$, $o^5 j^2$. Draw *bd* through $g^1 h^1 i^1 j^1$, and *be* through $g^2 h^2 i^2 j^2$, giving the vertical side miter cuts of the lower stave.

At *h* is shown the joint between the two vertical sections of the staves, where a purlin *p* is placed, to which the ends may be attached. At *g* is the section of the circular wall plate, on which rest the rafters. Where the towers are lofty, it will be found necessary to secure the wall plate to the stone cornice, by means of expansion bolts, so that they will be prevented from tilting under wind pressure.

67. Fig. 45 shows a perspective sketch of a conical roof with a bell cast at the eaves; also the method of sheathing as it would appear preparatory to receiving the final covering.

CARPENTRY

(PART 4)

CONSTRUCTIVE DETAILS

PLASTER GROUNDS

1. Plaster grounds are nailing strips secured to the studs of frame walls and partitions, and to brick and stone walls for the purpose of receiving the trim and also the plaster finish at breaks and openings. They consist of strips of wood from $\frac{5}{8}$ to $\frac{7}{8}$ inch in thickness and from 2 to 3 inches in width, according to the purpose they are to serve. Great care must be taken in placing grounds correctly to line and level, always keeping in view the character and dimensions of the finished trim. The edge of the ground abutting the finished plaster should always be beveled, so that the plaster can be more securely bonded.

In Fig. 1 is shown a method of applying grounds to which a baseboard may be fastened. In the angle formed at the meeting of the stud partition and the rough floor, a strip 1 in. × 2 in. is nailed to the studs, and at about the height of the baseboard above and parallel with this strip is nailed a similar strip. The upper edge of the ground is kept $\frac{1}{2}$ inch below the top of the baseboard, so that the baseboard will further bind the plaster in place. The upper edge of the strip

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is sometimes left square, but the plaster is better bound in place when the edge is beveled, as shown by the upper strip in the figure. To these strips the base is then nailed after the plastering is dry.

In dining rooms, kitchens, billiard rooms, etc., where a chair rail, or wainscot, is to be placed, another ground about 4 inches wide is nailed to the studs from 2 feet 6 inches to 3 feet above the floor, according to the height of the wainscot; and, in parlors, libraries, reception rooms, etc., a strip 1 inch in width is nailed from 1 foot to 2 feet 6 inches below the ceiling to receive the picture molding. This latter strip, however, is not generally used, as the picture molding may be placed directly on the surface of the plaster, wire nails being driven into the studs or furring strips, or into wooden plugs in case of brick partitions. Where a wooden cornice is to be carried around a room, a ground must be provided for it in the angle between the ceiling and the side walls. The surfaces of the stud partitions between these grounds are then lathed. The ceilings in ordinary work are lathed directly on the under side of the beams, but where a first-class job is desired, the beams should be cross-furred.

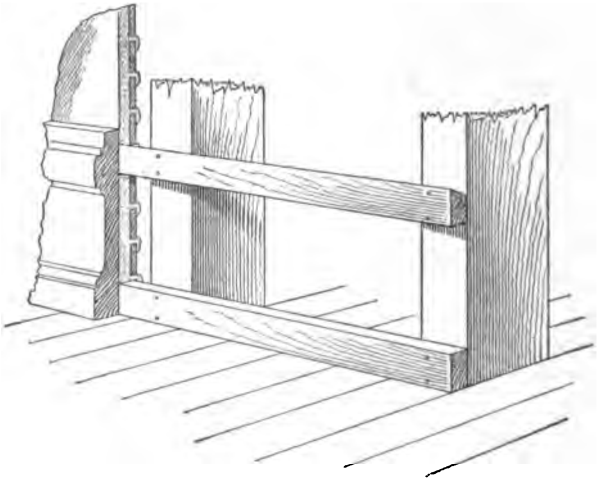


FIG. 1

AVOIDANCE OF PLASTER CRACKS

2. Natural settlement caused by shrinkage of the materials is not easily overcome, and when large timbers are used it cannot well be avoided. Seasoned framing timber is scarce and expensive, and the average architect can at best but require "that all beams, joists, studs, and framing material must be as dry as the market affords," which eventually means a series of cracks, seams, and fissures in the plastering. These are most prominent where the beams or joists run parallel with and support partitions, in which cases the partitions settle with the beams, leaving an ugly gap along the ceiling line. Where the beams sag in addition to shrinking, a series of zigzag diagonal cracks will appear on the surface of the wall. A similar effect will take place where a partition is supported by a tier of joists running at right angles thereto, and where it is located at or near the center of the span; all the joists shrink, but those

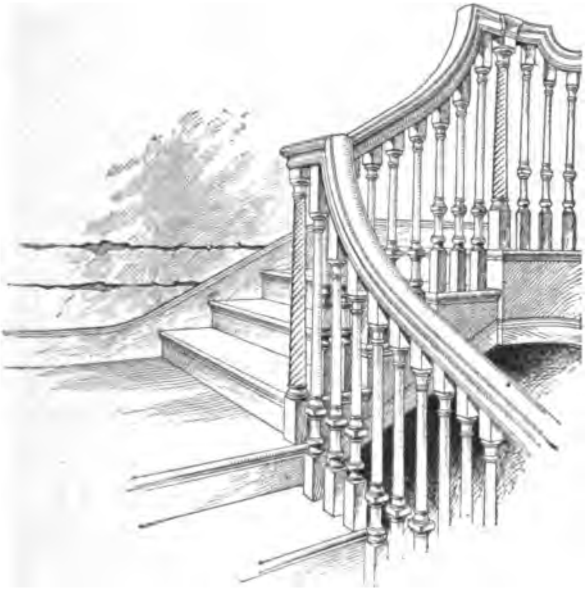


FIG. 2

near the center of the room sag more than those adjacent to the walls. To avoid these defects, it is necessary to have the supporting beams and joists thoroughly seasoned and of sufficient strength to carry the load without perceptible sagging. Whenever practicable, joist-bearing partitions should be placed directly over each other, the "feet" of the upper studs resting on the plate of the lower partition. By this means is obtained a continuous line of support from the cellar, where, if expense is a secondary consideration, the wooden supporting beams should be dispensed with, and a steel I beam or arched brick wall substituted.

3. The practice of setting partitions promiscuously on the joists is one to be condemned, not only on account of the subsequent distorted condition of floor levels, door frames, and doors, but also because of the difficulty of properly running vertical flues and pipe lines. The result of interposing a joist or joists in the thickness of a partition is shown in Fig. 2, which illustrates a carefully designed and well-executed piece of joinery. In this case, the trimmer beam was set flush with the face of the partition on the hall side, as suggested in Fig. 3, and the lath was simply nailed on the face of the beam. The beam, if 10 inches deep, might shrink anywhere from $\frac{1}{4}$ to $\frac{3}{8}$ inch, which means that the upper partition would drop down that much, and that the plaster, not being elastic, would bulge and crack. Had the trimmers been placed as shown in Fig. 4, in which the studs are continuous, plaster cracks would not have occurred.

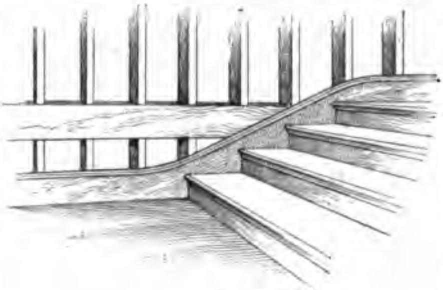


FIG. 3

4. Where a brick chimney stack passes up through the center of a house, it should be located with particular reference to the partitions that abut it. In many cases the studs are set just the thickness of the lath back from the face of the stack, as shown at *A*, Fig. 5. This is a grave error, as the sure outcome will be cracked and broken plaster. Chimneys are usually built with lime mortar and constructed hurriedly, it being required that the bricklayer complete a chimney in from 2 to 3 days. As the height in an ordinary two-story dwelling may be 45 feet, and as there are about 5 joints to each foot in height, there are about 225 joints from which the water must evaporate, causing shrinkage and settlement of the stack.

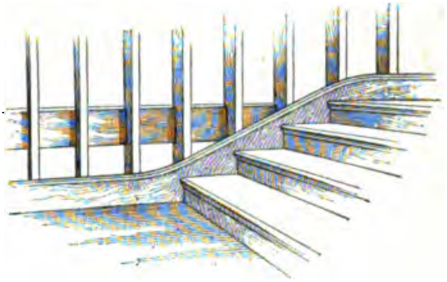


FIG. 4

To avoid excessive settlement, the stack should not be raised over 5 feet a day in dry weather, if laid with lime mortar; where time has to be considered, cement mortar should be used. With reference to the framework, the stack should be built free to move in a vertical direction, and where partition studding is placed in the manner shown at *B*, Fig. 5, this can readily be done. Cracks that subsequently occur will be in the internal angles, where they are not so noticeable and where they can be readily repaired without destroying the appearance of the walls. The heated brickwork of the stack also causes the studs to dry rapidly and to warp, thus producing a rift between the wall and the stack.

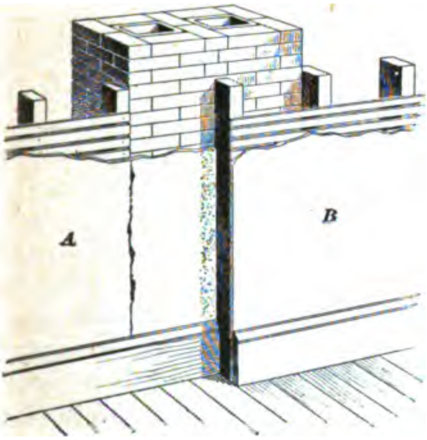


FIG. 5

5. When joists or studs are over 2 inches thick, they should have a strip nailed on their edge to obtain a better key for the mortar. To provide for this, and also to avoid cracks resulting from the joists becoming warped and twisted while drying, it is customary in good work to cross-fur the ceilings with $\frac{7}{8}'' \times 1\frac{1}{4}''$ strips set at 12-inch centers and well nailed to the joists. In this connection, the joists should be well braced with cross-bridging. A row of zigzag bridging in the height of studs will also render effective service and prevent them from twisting.

All external and internal angles of stud partitions should be made firm and rigid, otherwise subsequent shrinkage will cause the wall surfaces to separate and show fissures that cannot be closed. The practice of running the lath of the outer walls across the back of the abutting partition stud and simply butting the lath of the partition against it, is bad, and should never be tolerated.

False jambs should be well nailed to studs at door openings, so that the slamming of doors will not bring any strain on the plaster behind the casing.

Suitable plaster grounds should be placed for all base, wainscot, and door and window trim, especially where the latter adjoins brickwork. It is particularly necessary that the grounds should be of good, seasoned stock, as the slightest shrinkage will cause them to move and disturb the plastering when the trim is attached.

6. Unskilful and careless lathing is also responsible for many plaster cracks. Laths should be properly seasoned and kept from being soaked by rainwater after they have been seasoned. Where laths are unseasoned or have been carelessly piled and used in a wet condition, they will subsequently shrink and cause the appearance of an endless series of seams. The laths should not be too dry and parched, or they will absorb the valuable moisture from the plaster and cause it to become powdery and lose its toughness. This trouble, however, can be avoided by sprinkling the lath with water before applying the scratch coat.

Cross-grained laths are to be avoided, as in drying they curl and warp, break the bond of the plaster, and cause cracks. In good work, where sawed lath is used, special attention should be paid to this element, and none but straight-grained material allowed.

Where studs are set at 16-inch centers, laths should not be less than ⅜ inch thick; laths thinner than this yield under slight pressure and strain the plaster. A wall properly lathed and coated with ⅝ inch of common haired plaster, when thoroughly dried, should, when struck with the hand, be firm and compact and sound like a drum.

SIDING

7. Beveled and Novelty Siding.—**Siding** is the term applied to the material with which the exterior walls of a frame building are usually covered. There are two kinds: *beveled siding*, and *novelty*, or *German*, *siding*.

Beveled siding consists of sawed and planed boards in commercial lengths of about 16 feet and a width of from 4 to 6 inches. The thickness of this kind of siding is ⅝ inch at one edge, beveling back to ⅜ inch at the other edge, as shown in Fig. 6.

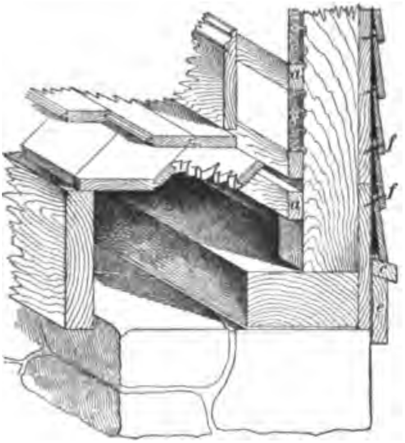


FIG. 6

Novelty siding has a uniform thickness of about ⅞ inch, except where it is rabbeted at the bottom to receive the chamfered edge of the next board below, and where it is chamfered at the top to fit the rabbet of the board next above, as shown at *b*, Fig. 7. Novelty siding is manufactured in single widths of from 5 to 9 inches, although in very cheap grades of work it is used in double widths, with a groove worked lengthwise through the middle to imitate the joint, as shown at *c*, Fig. 7.

The depth of the rabbet and the width of the chamfer limit the amount of lap that can be made with novelty siding; whereas, with beveled siding, one course may overlap the other any distance within the limits of the width of the material. It is preferable, therefore, to use beveled stock on all first-class work, though it costs a trifle more and requires more labor to put it in place. Beveled siding is more durable on exposure to the weather, less liable to crack and check, while its thinness renders it easily dried out; also, the stock is more likely to be well seasoned than that used for novelty siding.

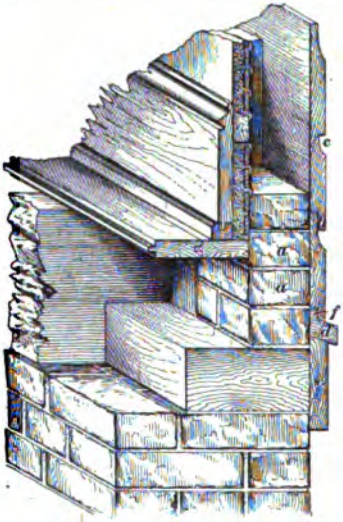


FIG. 7

8. Method of Siding a Building.—Before the siding is put on the building, a *water-table* *e*, Fig. 6, and Fig. 7, extending about 1 inch below the sill, is placed all around the structure. The water-table has a pitched cap, shown at *c*, Fig. 6, and *d*, Fig. 7, which serves the purposes of receiving the water that runs down the side of the house and of shedding this water off to the ground before it works its way into the foundation, to rot the sill and render the house damp and unhealthful.

The cap of the water-table is pitched in order to give its top surface an inclination of from 15° to 30° to the horizontal; it also has a tongue worked on its top so as to form a seat for the lower piece of siding and thus make a water-tight joint, as shown at *f*, Fig. 7.

Over the sheathing of the building, from the water-table to the plate, is laid one or more thicknesses of heavy felt or resinous building paper, to prevent drafts from working through the cracks and joints. Over this paper, and above the water-table, the siding is laid in horizontal courses, each course being nailed through its lower edge, as shown at *f*, Fig. 6. Cut nails $2\frac{1}{2}$ inches long and having flat heads should be used, the siding being nailed only at the studs and the nails set in so that they may be puttied over. Beveled siding should be carefully gauged as to lap, so that the edges may be made to run in line with the horizontal lines of the window and door trim.

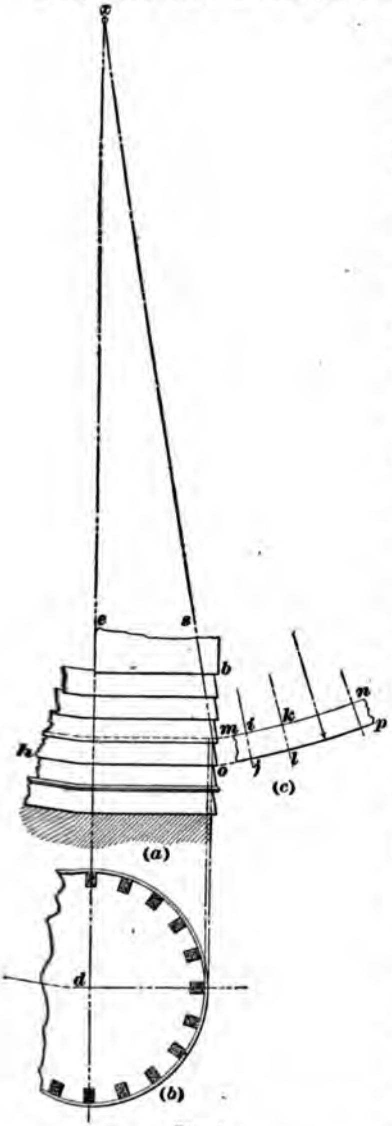


FIG. 8

9. Circular Siding. When a circular tower or a semicircular bay window exists in a building, the siding must have its lower edge convex and its upper edge concave, in order that these edges may lie in horizontal lines when the siding is bent around the curved front of the tower.

Fig. 8 shows the elevation (*a*) and the plan (*b*) of a portion of a circular tower, the siding of which must be worked with curved edges, as shown at (*c*). To find the radius and extent of this curvature, an axial line *de* is drawn through the center of the tower and prolonged toward *e* indefinitely. A line *os* is then drawn as a continuation of the direction of the inside slanting surface of one piece of the siding, and is prolonged until it intersects the axial line *de* at *x*. With this point of intersection *x* as a center, and radii equal to *xo* and *xm*, respectively, the arcs *op* and *mn* are described. Then, the figure *mnpo* will be of the form and curvature necessary to secure the level lines on the top and bottom of the siding after it is bent around the tower in the position shown at *oh*.

This form *mnpo* should be first cut out of heavy paper, and then, using the paper as a pattern, the curve can be traced on each strip of siding and worked out with a draw knife and a plane. The exterior distance from center to center of the studs shown in the plan (*b*) should be marked off on the pattern piece with lines converging toward the point *x*, as shown at *ij*, *kl*, and all the butt joints between the ends of two pieces of curved siding should be cut on one of these lines, in order to insure a properly fitting joint and to have the ends meet in the center of a stud. When the siding is put on the building, its lower edge is laid and nailed to a line previously marked for it on each stud.

Where the siding is specially worked with a vertical back, so as to hug the sheathing, it can be applied in straight pieces. In this case, the surface of the tower is *cylindrical*, while in the other, where beveled siding is used, the surface of each layer is *conical*.

VERANDAS

10. The details of construction of the exterior features of a building require, on account of their exposed situations, especial consideration in order to insure the fulfilment of the purposes required of them. Veranda construction must provide all the requirements of an outdoor sitting room in fair weather, and at the same time insure the side of the house on which it is built against the invasion of water and dampness during a heavy rainstorm; it must also permit the rapid drying of the floor and timbers after such a storm is over.

11. Details of Veranda Construction.—In Fig. 9 is shown a perspective view of the details of construction of a veranda. The floor *d* pitches at the rate of $\frac{1}{4}$ inch to a foot from the house line to the front edge at *e*, in order to drain the water off as soon as it falls. For the same reason, the boards of the floor are laid across the veranda, as shown; otherwise, the water would lodge in the joints and soon rot out the material.

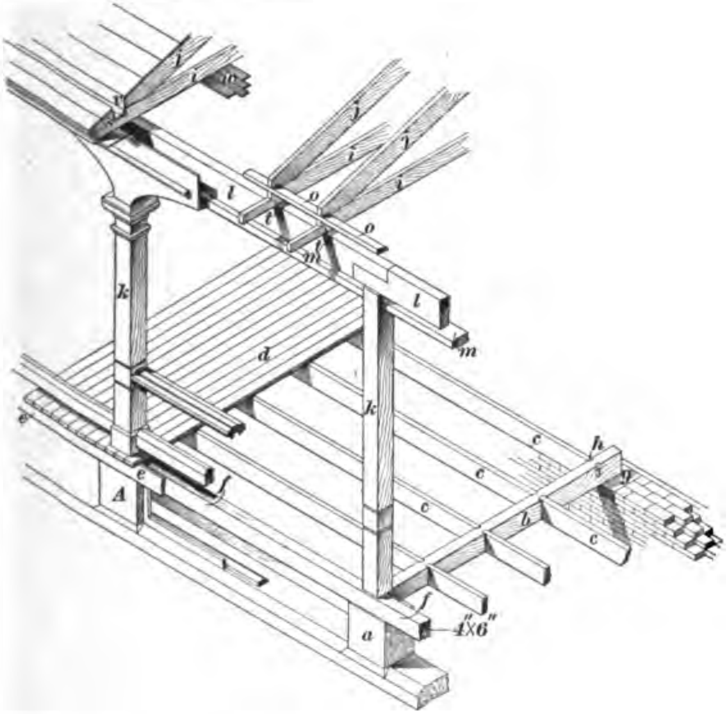


FIG. 9

In order to run the floor boards in this direction, it is necessary to provide means of framing the floorbeams lengthwise of the structure. Therefore, under each veranda post is built a brick or a stone pier *a*, on which is laid the 4" × 6" sill *f*, extending the full length of the veranda. From this pier, a girder *b* extends to the foundation wall of the house, where a stone templet *g* is built in to receive it; or, where the veranda is narrow, the girder simply rests on the brickwork without any templet. The veranda floor joists *c* are then framed into the girder, as shown at *h*, and securely spiked in place. In frame buildings, the girders usually rest on a ledger board that is well spiked to the sheathing.

In order to secure the necessary pitch of ¼ inch to the foot for the veranda floor, the girder *b* may be laid at the necessary inclination; or, its top may be either planed or sawed down so that it has the proper pitch and the bottom allowed to remain level. In either case, the beams are framed so that their tops are flush with the top of the girder, and the flooring is laid directly on them.

12. Veranda flooring should be at least 1¼ inches in thickness, tongued and grooved, and laid in white lead; that is, the joint between two boards should be thoroughly filled with a pasty composition of white lead and raw linseed oil. This is accomplished by coating the edges of the boards with the mixture and driving them tightly together as they are laid. A good material for veranda floors is clear, dry white pine, heart stock, that is free from all imperfections.

13. Veranda posts, whether square, as at *k*, Fig. 9, or turned, should be of selected, good, sound, dry timber, which is the heart wood of the tree. After being sized to the required dimensions, the posts are carefully sawed squarely across the ends to an even length; the pores of the lower end of the wood are then filled with white lead, and the post is usually set up on the finished floor of the veranda.

Porch posts placed directly on the porch floor will soon rot, however, as shown in Fig. 10 (*a*). For this reason, the bases of porch posts are often placed on metal shoes or cast-iron buttons 1 inch thick and 2 inches in diameter that raise them clear of the porch floor. At (*c*) is shown an iron button of this kind. Four of these buttons are placed under a square post, the metal pins being let into the floor and the post and bedded in white lead. Another method is to rivet the buttons to an iron plate, which in turn is secured to the bottom of the post, as shown at (*b*).

14. A girder *l*, Fig. 9, connects the upper ends of the veranda posts and serves to support the ceiling beams and rafters *i* and *j*. On the ceiling beams *i*, the plate *o* is spiked, and the feet of the rafters *j* are notched out to fit over it, as shown. The inside ends of the beams and rafters are notched over a ledger board in the same manner as second-story floorbeams, where the building is of frame construction; in brick or stone walls, they are built in and anchored.

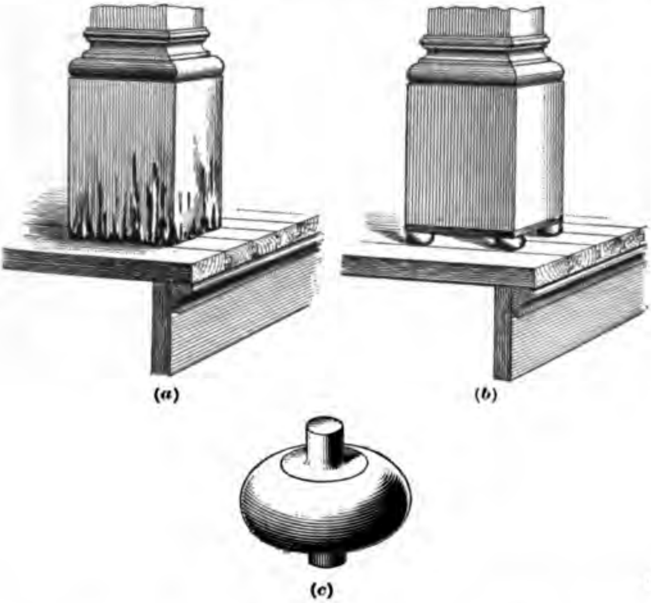


Fig. 10

15. The roof of this veranda, which pitches at the rate of 4 inches to the foot, should be boarded over with matched roofing boards and then covered with tin, copper, or flat tile bedded in asphalt, as the inclination is too flat for shingles or slate. The gutter is formed by cutting out about one-half the depth of the projecting portion of the ceiling beams,

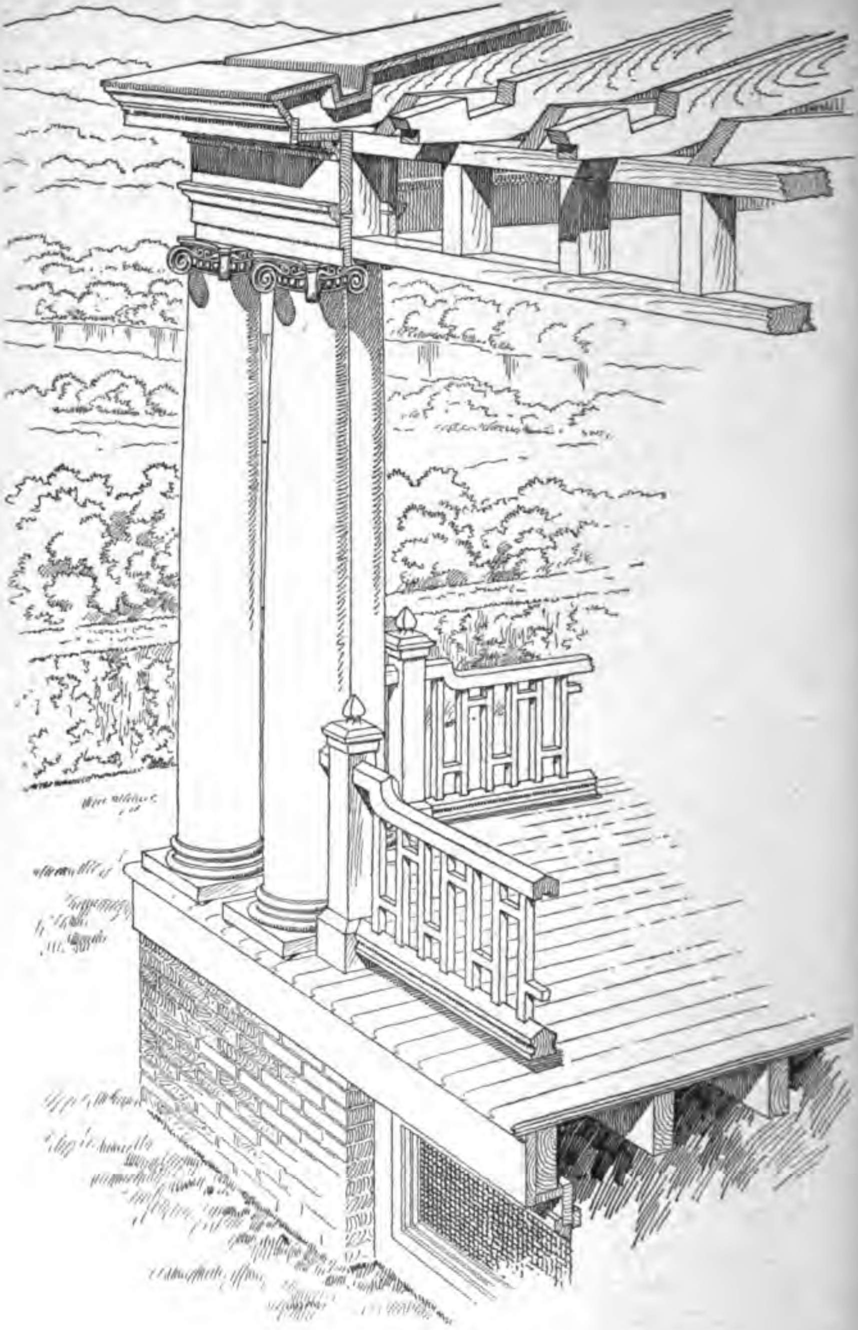


FIG. 11

as shown at *t*, Fig. 9, and sawing the lower end of the rafters so as to stand plumb over the girder *l*. The continuation of the roof pitch below the gutter is maintained by spiking to each ceiling beam a triangular piece *s* and boarding it over to form the roof slope and gutter *v*. The beam soffit casing is shown at *m*.

16. The ceiling of the veranda may be formed of narrow strips *w* of pine or hardwood laid on and blind-nailed securely to each of the ceiling beams *i*. A better appearance is presented when the ceiling boards are placed at right angles to the building, in which case blocking or furring strips should be run at right angles to the ceiling beams. Sometimes, the veranda roof is left open on the under side, exposing the timber construction. When this is the case, no ceiling beams are used, but the exposed portions of the rafters are planed and dressed; the roofing boards are of selected narrow stock, planed and matched, and laid with their finished side downwards.

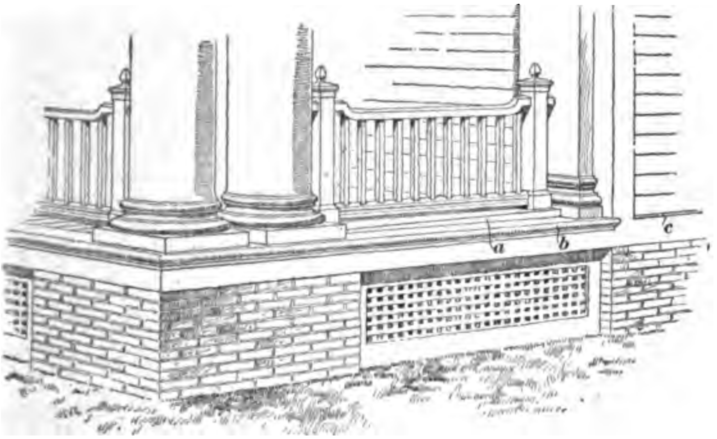


Fig. 12

17. Figs. 11 and 12 show the method of construction used for a porch such as would be found on a house of the Colonial type. At *a*, Fig. 12, is shown a method of changing the pitch of the porch beneath the balustrade so that the nosing at *b* may be level and line up with the water-table *c*.

18. The method known as **chamfering** is sometimes resorted to as a means of relieving exposed timbers of the sharp angle, or corner, where their finished faces meet. It consists of cutting off the corners of a girder, ceiling beam, veranda post, or other exposed timber for a part of its length and stopping the *chamfer* against an oblique cut, called the *chamfer-stop*, made at an angle of about 45° or 60°, as shown at *a b*, Fig. 13, where *b c* is one of the chamfered corners.

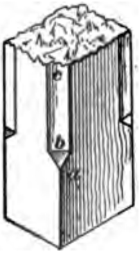


FIG. 13

19. Chamfered corners are very conspicuous in Swiss-cottage architecture, where the entire framework of the building is more or less exposed and ornamented. The width of a chamfered edge is entirely a matter of taste. Of course the chamfer should never be so great as to impair the strength of the timber, while, on the other hand, it should be prominent enough to be clearly seen from any point where the timber so treated is conspicuous. This is especially the case with girders and floorbeams, which, being above the eye, require a somewhat heavier chamfer than posts and railings.

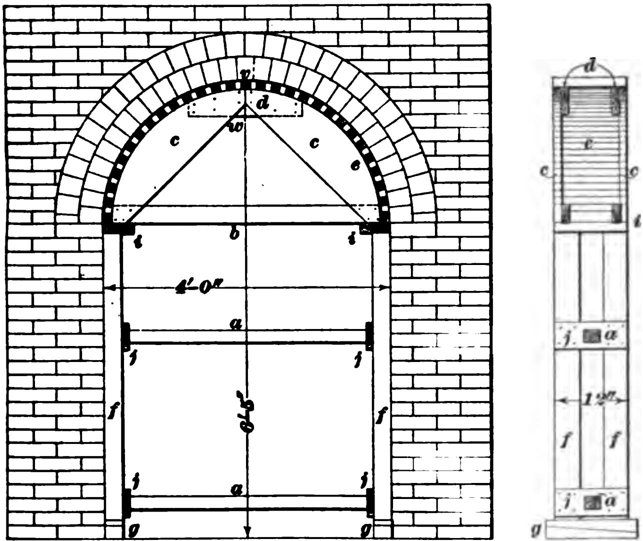
CENTERS FOR ARCHES AND DOMES

20. **Arch Centers.**—Where any portion of the outer or inner walls of a building is to be built of brick or stone, and the openings in these walls are to have curved heads, the carpenter will be called on to make and set in place wooden templets, or **centers**, as they are called, on which the mason can build the arches. These centers are allowed to remain in place until the mortar has thoroughly set and rendered the arch self-supporting.

21. **Center for Semicircular Doorway.**—In Fig. 14 is shown a wooden center for a **semicircular doorway**

in a 12-inch brick wall. At (*a*) is shown the side view of the center and its supports, and at (*b*) the elevation of the center in position in the wall. The faces of this center are each composed of two pieces *c* of 1¼-inch plank sawed to the proper curve. These are held together at the bottom by the tie-piece *b*, which is securely nailed, as shown, while the joint at the top is secured by a fish-plate *d* nailed to both pieces on the inside of the boards.

Two face pieces formed in the manner just described are then joined together with small strips, called *lagging*, 1¼ inches thick, 1½ to 2 inches wide, and 12 inches long, as shown at *e*. The bottoms of the face pieces are secured by two *caps i* nailed to each face, and under these caps are placed the supports *f*, when the center is set in the opening ready to be built on. The lower ends of the supports *f* should not rest directly on the sill of the opening, but on two slip wedges *g*, which are driven out by degrees after the masonry has set, thus allowing the arch to settle down gradually to its own proper bearing. The braces *a* are



(*b*) (*a*)

FIG. 14

inserted between the cleats *j* to maintain the supports in a vertical position against the jambs of the opening. All wooden arch centers may be framed very nearly in this same manner, except in very large spans, where heavier timbers must be used.

22. Semielliptical Centers.—Centers for **semielliptical arches** are formed in the same manner as those for semicircular arches, but usually require more pieces in the curved faces. For this reason, it is advisable to lay out, on paper, a semiellipse of the required height and span and make a templet. Then, with this templet, lay out the curved line on the several pieces of plank that have previously been arranged to occupy about their proper position in the finished center, as *a*, *b*, *c*, *d*, and *e*, Fig. 15. The curved edge is then sawed out on each piece separately, the ends sawed to the proper miter line, and fish-plates nailed on the back in the same manner as *d* was nailed on *c* in Fig. 14. When great strength is required, it is sometimes advisable to make these fish-plates as large as their face pieces *a*, *b*, *c*, *d*, and *e*, and miter their ends to an even joint, as shown in Fig. 15. The ends are secured in place by the tie-piece *f* and the

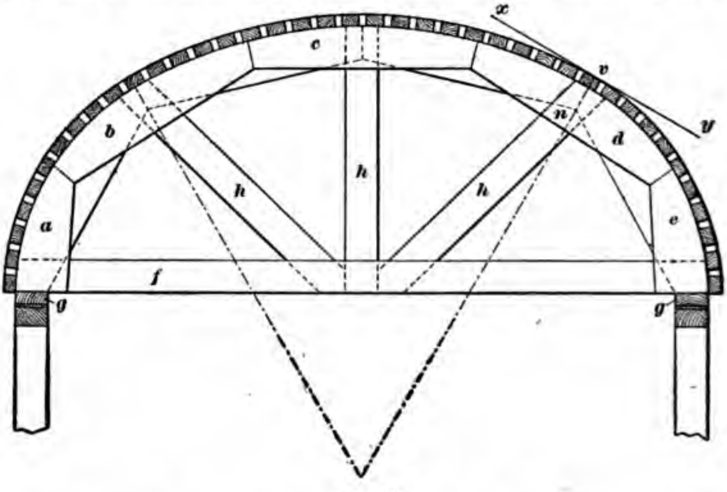


FIG. 15

caps *g*, while the center is strengthened by struts *h* extending from the tie-piece *f* to each of the intermediate sections of the face pieces, as *b*, *c*, and *d*. Small $1\frac{1}{4}'' \times 2''$ strips are then nailed on the curved edges in the same manner as for the semicircular center, their length being equal to the thickness of the wall in which the arch is to be built. A perspective of this arch center is shown in Fig. 16.

23. Direction of Joints in Centers.—In all wooden centers, the joints between the different sections of the face pieces should always be in a line perpendicular to a tangent at the point where the joint line intersects the curved line of the arch. For example, in Fig. 15, the joint line *n v* of the fish-plates is perpendicular to the line *x y*, which is tangent to the curve at *v*. These joint lines will all converge toward the center from which the curve is struck when the arch is semicircular, as *v w*, Fig. 14, but in other curves they can be found only by first drawing the tangent, as in Fig. 15.

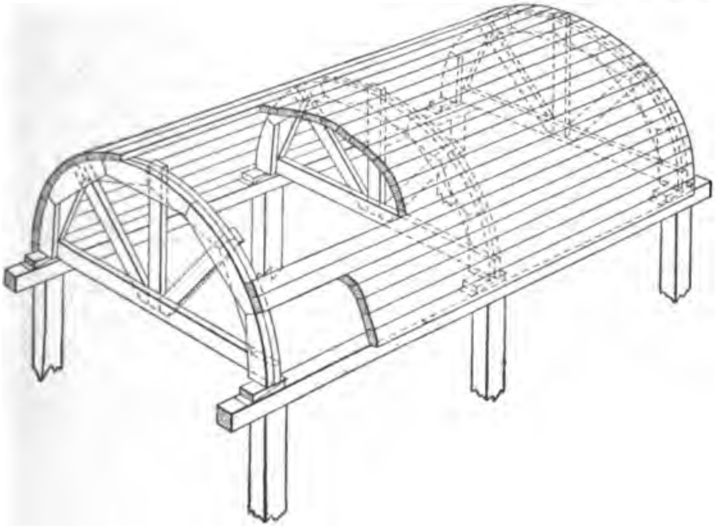


FIG. 16

24. Trimmer-Arch Centers.—Centers for **trimmer arches** are built to extend from the brick wall of a chimney to the header beam of the floor, where it is framed around a fireplace, as shown in Fig. 17.

A characteristic difference between the trimmer-arch center and those previously described is that the wooden center is generally left in place and remains in the building after the masonry arch is laid over it. When the mason builds the brickwork of the chimney, he corbels out one course of brick about 1½ inches at the level of the under side of the floorbeams, as shown at *e*. The carpenter then builds the center so that one end rests on the brickwork at *e* and the other end is notched over a 1½″ × 2½ or 3″ cleat *d* nailed on the header beam *a*. The face piece of the center *c* is 1¼ inches in thickness, and its upper edge, on which the lagging *f* is nailed, is sawed to the curve of the arch, so that the small end will be about 1½ inches in thickness where it rests on the brickwork at *e*, and about 4½ or 5 inches less at the large end than the depth of the floorbeams. The number of ribs like *c* required for a trimmer-arch center depends on the length of the hearth that is to be built over it. If the ceiling below is to be plastered, however, it is desirable to have a rib opposite each tail-beam supported by the header, thus avoiding the waste of lath. Where the distance of the header is not more than 18 inches from the face of the wall, the lath may be run at right angles thereto and nailed at the wall end to the cleat *g*.

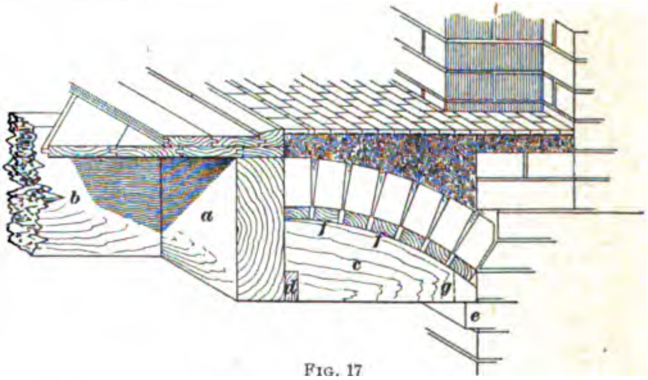


FIG. 17

25. Dome Centers.—When the roof of a building is carried up, either wholly or in part, in the form of a hemisphere, or semiellipsoid, it is called a **dome,** and the rafters supporting it must be sawed or bent to the required curvature.

26. Hemispherical Dome.—**A hemispherical dome** is shown in Fig. 18, in which (*b*) is a half plan and (*a*) the sectional elevation. The curve of the dome is described from *s′* as a center with a radius *s′e′*. This is also the curve

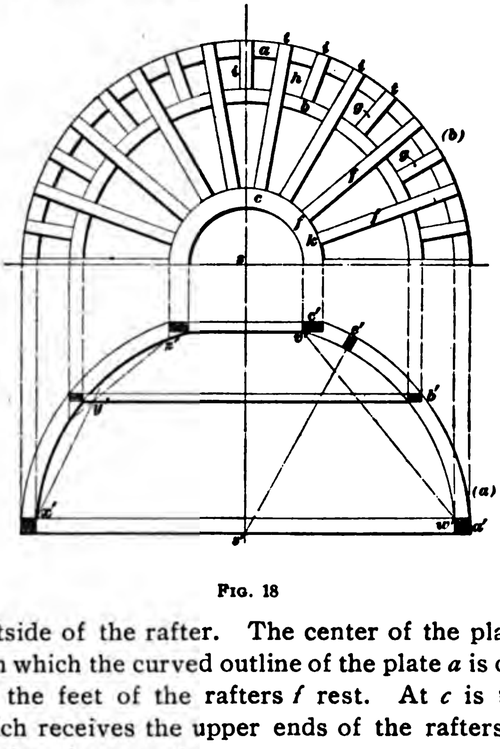


FIG. 18

of the outside of the rafter. The center of the plan *s* is the point from which the curved outline of the plate *a* is described, on which the feet of the rafters *f* rest. At *c* is the upper plate, which receives the upper ends of the rafters *f* and at the same time forms a circular opening, called the *eye of the dome*, that admits light and air. About half way up the curved outline, at *b′*, is shown a line of purlins cut in between the main rafters to receive the upper ends of the small jack-rafters *g*. This line of purlins is shown at *b* in the plan, and it is at about this point that the main rafters are spaced at a uniform distance of from 16 to 24 inches apart, the jack-rafters being then inserted between their lower ends and spiked to the plate a and the purlins b.

The method of forming, or building up, the plate a is the same as described for the conical roof in *Carpentry*, Part 3, and the rafters are bent or sawed in the same manner as the curved rafters of the ogee roof there described. Where bent rafters are used, they are composed of thin strips bent over a form, the layers being nailed together. When the dome is for exterior effect only, and the inside is not to form part of any particular room, the rafters need not be sawed to a curved line on the under side, but may retain the straight edge of the board from which it is sawed, as shown by the dotted line $v'w'$; or, if composed of two pieces, by the lines $x'y'$ and $y'z'$.

27. Methods of Boarding Hemispherical Domes. There are two methods of boarding over the curved surface of hemispherical domes. The first method is shown in Fig. 19, where $n o t$ is the curve of one-half of the plan of the dome, and $a b$ is the outline of the curve of the elevation. From the center c of the plan is drawn a line $c d$ of indefinite length, but at right angles to $c b$, the axis of the elevation, and at $e r$ on the plan is laid off the width of one of the roofing boards, $o e$ and $o r$ being each equal to one-half the width of a board; the lines $e c$ and $r c$ then represent this board in place on the plan. The line $a b$ is then divided into any number of equal parts, the points of division being marked s, s_1, s_2, etc., and these parts are laid off on $c d$ from o, so that $o d$ represents the length of the line $a b$ folded out straight, and $o f$, $o f_1$, etc. are each equal to $a s$, $a s_1$, etc. From s, s_1, etc. perpendiculars are now drawn through $c o$, cutting $c e$ and $c r$ at l, l_1, etc. From the points f, f_1, etc., on the line $o d$, draw lines at right angles thereto, and make $t f$ equal to one-half of $l l$, $t_1 f_1$ equal to one-half of $l_1 l_1$, etc. A curved line drawn through the points t, t_1, etc. to d will be the outline of the *gore*, or covering board required, and if this is laid out on a sheet of heavy paper and cut to the lines, it will form a templet from which all the boards may be marked and cut. To support the gores, curved purlins, as shown at *e'*, Fig. 18, are inserted between the rafters. These purlins are spaced to suit the curvature.

A conical roof is boarded in the manner just described, and small purlins must also be framed in between the rafters to receive the boarding. The boarding of the conical roof, however, requires no curvature, but simply tapers from the plate toward the apex in a straight line.

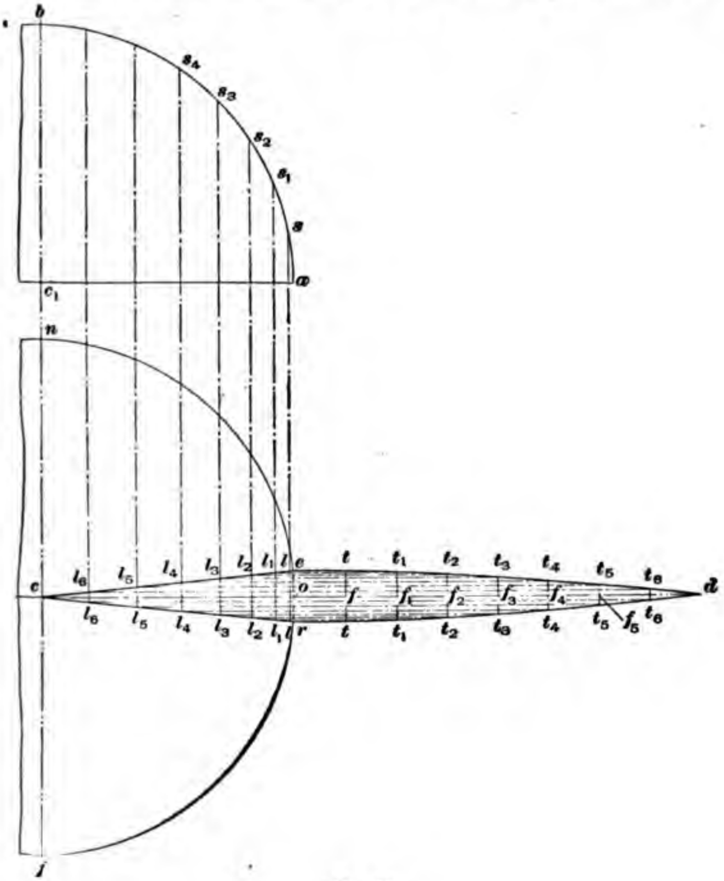

b
s_4
s_3
s_2
s_1
s
a
c_1
n
l_6 l_5 l_4 l_3 l_2 l_1 l e t t_1 t_2 t_3 t_4 t_5 t_6
c
o
f f_1 f_2 f_3 f_4
d
l_6 l_5 l_4 l_3 l_2 l_1 l r t t_1 t_2 t_3 t_4 t_5 f_5 t_6
f

FIG. 19

28. The second method of covering the dome is shown in Fig. 20. The boards in this case are laid in short horizontal courses as at *f o b a*. The springing line of the dome is shown at *w a*. One-half the curve of the elevation *a e*, Fig. 20, is divided into any number of equal parts as *a b*, *b c*, *c d*, etc., each part being equal to the width of one of the covering boards. The line *b c* is drawn from the point *b* through the point *c* and is prolonged until it intersects the axis *f e* of the dome, prolonged, at *h*; then, from the point *c* through *d* a line is drawn until it intersects the axis line at *j*, and so with each of the other parts, until the points *k*, *l*, *m*, etc. on the axis line are obtained. With *h* as a center and a radius *h b*, the curve that will form the lower edge *b q* of the board *b c* can now be described, while with the same center and a radius *h c* it is possible to describe the arc *c p* that marks the curvature of the upper edge of the board. From the point *j* as a center, and with the radii *j c* and *j d*, the arcs *c t* and *d u* are described; these mark the outline of the board *c d*. In the same manner, the outline for each of the boards in the dome is marked, until the top opening, or eye, is reached, which, when not to be framed, is closed over with a flat, circular piece of board, the center of whose curvature would be at *e*.

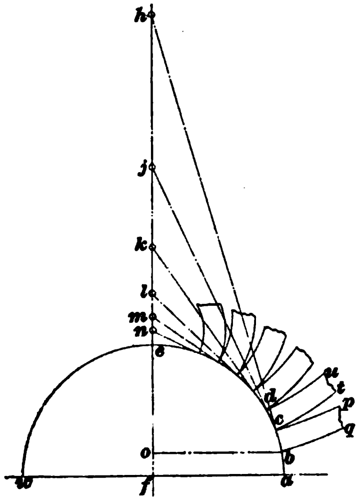


FIG. 20

29. When a dome is comparatively small and great neatness is required in the perfection of its semicircular outline, it is desirable that the joints should be planed down to round the surface, whether the boards run horizontally around the dome, as in Fig. 20, or extend from bottom to top, as in Fig. 19. When a dome is large and well above the eye, as on the roof of a high building, such nicety is not required, as the covering material will round the form to the desired outline.

30. **Interior Domes.**—An **interior dome** is sometimes built under a flat roof, and is very commonly seen over a stair hall that is illuminated through an ornamental glass skylight inserted in the eye of the dome. These interior domes are generally elliptical in form, but whether the outline is a semicircle or a semiellipse, the method of framing is precisely the same.

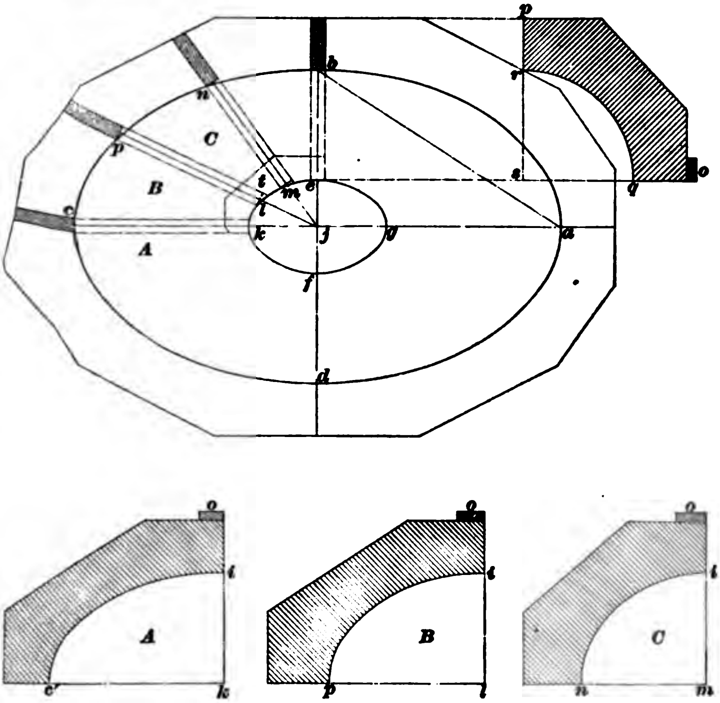


Fig. 21

Fig. 21 shows the plan of an interior dome, the outline of which is an ellipse having a length *ac* and a width *bd*. In the center is shown the eye, whose length *kg* and width *ef* are in direct proportion to the length and breadth of the larger ellipse. The plane of the dome *abcd* is formed by cutting the curved sides from separate boards and nailing these boards around the opening framed in the floor or roof over which the dome is to be built. The eye of the dome is made of four or more pieces of board securely nailed together to receive the upper ends of the ribs when set in place.

There will be four sets of these ribs, each set representing one-quarter of the dome. The rib *be* will have for its curve a quarter circle with a radius *eb*, as shown at *opqr*, where the points *e* and *b* have been projected to *q* and *r*, and the arc *rq* has been struck from *s* as a center, with a radius *sr* equal to *eb*. The other ribs *mn*, *lp*, and *kc* have each the curve of a quarter ellipse, the shorter semiaxis of which, in each case, is equal to the height of the rib *be*, shown at *sq*; their larger semiaxis will be the length of each rib in plan, as *mn*, *lp*, and *kc*. These ribs are shown at *A*, *B*, and *C*, each of the vertical heights *ki*, *li*, *mi* being equal to *sq*; on each of them at *o*, is shown the section of the eyepiece *t* that holds them in place. Such a dome as this should be lathed with wire lath, as it is impossible to preserve the curvature with wooden lath.

31. Groined Ceilings.—A **groined ceiling** is formed by the intersection, or crossing, of two arched passageways. The framing required for a ceiling of this kind is shown in Fig. 22, where *A* is an arched passage 3 feet 8 inches in width intersected by another arched passage *B*, 6 feet 4 inches in width. At *bfd* is shown the soffit of the arch over *A*, revolved on the exterior line of the thickness of its material to keep it clear of the other details, and at *bgc* is shown the soffit of the arch over *B*, revolved in a similar manner. The lines of intersection of these arched, or vaulted, surfaces are called *groins*, and they occur on the diagonals *ab* and *cd*, which intersect at *o*. If both passages were of the same width, both arches could be semicircular, as is the arch over *A*; but as *B* is much wider, and at the same time no higher, than *A*, the curve of the arch over *B* becomes a semiellipse, with its longitudinal axis *b c* equal to the width of the passage, and its semitransverse axis over the axial line of the passage *B* equal to the height *f q* of the semicircular arch over *A*.

The groins *a b* and *c d* will also be semiellipses. Their curvature and the necessary dimensions for the ribs may be obtained by erecting *o n* perpendicular to *a b* and equal in length to *f q*, and then describing the quarter ellipse *b r' m' n*, with *o n* as its semiminor axis and *o b* as its semimajor axis. These semielliptical arcs may be described according to the method explained in *Geometrical Drawing;* or, points on the curves may be determined by projection. From any points on the semicircular arch, as *i*, *j*, *k*, *l*, draw the lines *i m*, *j r*, *k v*, *l e* parallel with *o f*, and where these lines intersect the diagonal line *o b*, erect perpendiculars both to the groin and to the line *b c*. Then, by laying off successively on these perpendiculars the distances *i h*, *j 2*, *k 3*, and *l 4*, from *m*, *r*, etc. on the line *a b*, and the same distances from the line *b c*, points will be established through which may be drawn the curves *b n* and *b z g*.

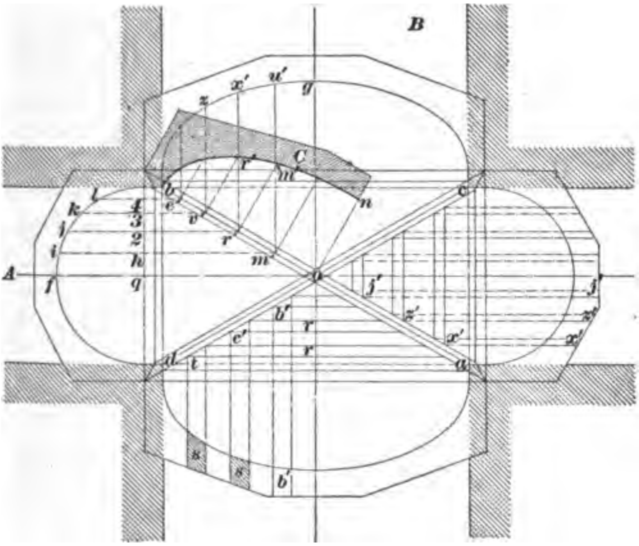


FIG. 22

Between these intersecting groin ribs, small jack-ribs, or rafters, *r* are framed, and their curved outline is precisely the same as that of the main ribs *b g c*, Fig. 22, as far as they reach on each side of the center, or axial, lines. The main ribs and jack-ribs are spaced from the center *o* at a uniform distance of 16 or 24 inches on centers, according to the span, and lath is then applied in the usual manner to the under side.

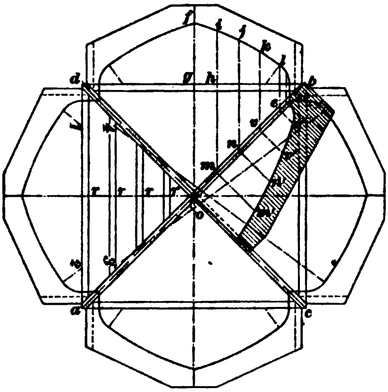


FIG. 23

The lengths and cheek cuts of these jack-ribs may be determined by projecting their points of intersection with the groin ribs to the curve of the main ribs. Thus, from the points j', z', x' and b', c', t on the groin ribs *o a* and *o d*, Fig. 22, draw the lines $j'j'$, $z'z'$, etc. The exterior lines of each rib will determine the length of the side of the jack-rib that is farther away from the point *o*, and the interior lines for each rib will mark the length of the jack-rib that is nearer the point *o*. Then, if these lines are marked on opposite sides of the jack-rib, a line connecting their ends across the edge of the jack-rib will mark the cheek cut, as shown for the two longer jack-ribs at *s*.

32. Pointed Arches.—A **pointed arch** is one composed of arcs struck from two or more centers, the curves of which are not tangent to each other, but meet at an angle as shown at *f*, Fig. 23. The ceiling of two intersecting passages, which are vaulted in the form of a pointed arch, or vault, forms a groined vault not unlike that just described.

33. Pointed Vaults.—The **pointed vault** shown in Fig. 23 is composed of the arcs of two circles described from four centers *1*, *2*, *3*, *4*, as shown by the radial lines. The smaller arcs at the sides of the vault, described from centers *1* and *2*, are tangent to the larger ones described from centers *3* and *4*; but the two arcs last named are not tangent to each other, and therefore form a point at the center that is over the axial line of the passage. As explained in Art **31**, the diagonal, or groin, ribs are laid out by means of lines projected from points on one of the arches parallel with the axial line *fo*, and intersecting the groin line *ab*. Perpendicular to the groin at these points of intersection, the lines *mm'*, *nn'*, *vv'*, and *ee'* are drawn equal in length to *ih*, etc., respectively, and through the points *m'*, *n'*, *v'*, *e'*, the curve of the groin is described. The wooden rib, the under side of which forms the contour of this groin, is shown by the shaded portion.

Between these intersecting groin ribs small jack-ribs *r* are framed, and their curved outline is precisely the same as that of the main ribs *dfb* as far as they reach on each side of the center line. The main ribs and jack-ribs are spaced from the center *o* at a uniform distance of 8, 16, or 24 inches, according to the span, and lath is then applied in the usual manner to the under side. The bevels for cutting the ends of the jack-ribs are found in the manner previously described.

34. Pendentives.—Another method of finishing the roof or ceiling over the intersection of two passageways, is to construct over the crossing a hemispherical dome, when the passages are of the same width, and an elliptical dome when they are of different widths. The effect of this treatment is shown in Fig. 24, where the passage *A* intersects and crosses the passage *B*, and the sides of each one, prolonged by dotted lines, form the rectangle *abcd*, which is

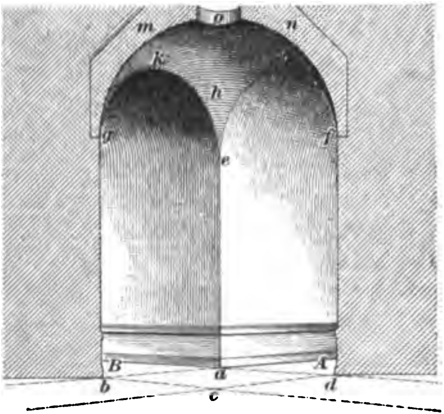


FIG. 24

the plan of their intersection. The roof of each passage is vaulted over with a semicircular arch, as *g k e* and *e l f*, while from the points *e*, *f*, and *g*, where these arches spring, there also starts a hemispherical dome *g m o n f*. The corners *e*, *f*, and *g* gradually round over to the eye of the dome at *o*, and at the same time broaden out in a fan shape over each of the adjacent arches, as at *e k l*.

This spherical triangle *e k l*, which brings the curvature of the dome down to the corner of the passage at *e*, is called a **pendentive,** and there is, of course, one of them over each of the corners *a*, *b*, *c*, and *d*.

35. To develop the curvature of the ribs and construct the framework for the dome and pendentives, the plan of the intersecting passages is first drawn, as shown at *a b c d*, Fig. 25. Next, the axial lines of the passages *A A* and *B B* and the diagonal lines of their intersection, over which the ribs $v' a'$, $g g'$, *a c*, and *b d* are located, are drawn. Then, with a center *o* and a radius *o a*, draw a circle through the four corners of the plan *a b c d*; this circle will represent the plan of the dome. If this dome is now cut on the line *d c* at right angles to its plan, the section on the vertical plane will be the semicircle *c e d*, which is the arch over passage *A*.

There will be four of these arch ribs, one over each of the lines *a b*, *a d*, *c b*, and *c d*, and that part of the dome which would extend into each of the passages, as at *a v d*, is cut off by the arches over the entrances to the passages *A* and *B*. Now, as the dome is a hemisphere, any section of it through the center of its plan will be a semicircle, the radius of which is the same as that of the circular plan. Thus, the semicircle *b c d* can be considered as a revolved section through the dome on the diagonal rib *b d*; *b c u y* will then represent that rib as it would appear when cut out of its plank, with its lower end *b* resting on the corner, and its upper end *c* standing over the center *o* a distance of *o c* higher than the end *b*.

Four of these ribs will constitute the diagonals *a c* and *b d*, and the jack-ribs, as *o g*, *o h*, *o i*, etc., will have the same curve exactly as far as they reach, but their upper ends will be beveled and pointed to fit in around *o*, while their lower ends will require a plumb-cut and a cheek cut to fit them against the arch pieces at *a b*, *a d*, *c b*, and *c d*.

36. To find the lengths and cuts for these jack-ribs, from the points *z* and *s*, Fig. 25, where the sides of the ribs *o a′* and *o b′* intersect the side of the diagonal *o b*, draw *z u* and *s t* parallel with *o c*. The line *z u*, where it crosses the rib *b c u y*, will mark the shoulder from which to bevel the end of the rib *o a′*, and the line *s t* will mark the shoulder from which to bevel the rib *o b′*. The end piece *u c* will be cut off, as the rib *o b′* does not reach to the center *o*.

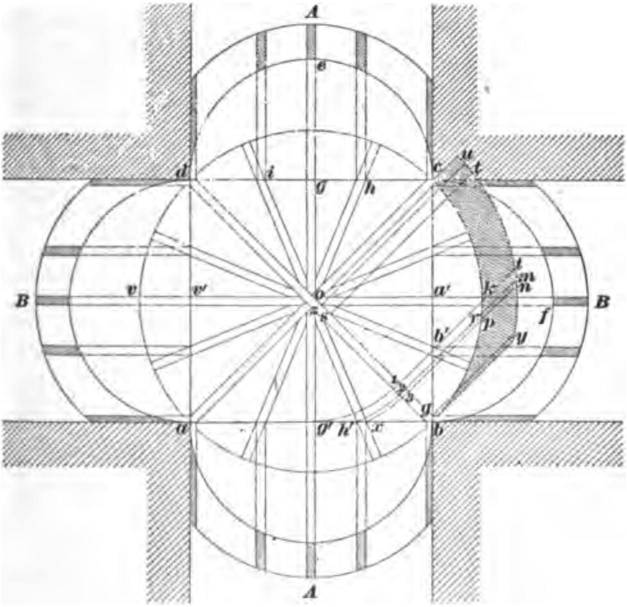
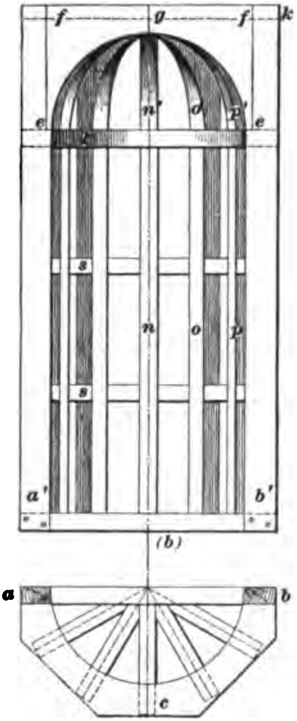


FIG. 25

Now with *o* as a center and the radii *o g′*, *o h′*, and *o x*, describe the arcs *g′ 1*, *h′ 2*, and *x 3*, which will measure the lengths of each side of these jack-ribs on the diagonal rib *o b*. The lines *1 l*, *2 m*, and *3 n* perpendicular to *o b* will cut the rib *b c u y* to the required lengths for the jack-rafters; *c u l k* will be the pattern for four of the jack-ribs og', oa', og, and ov', the cheek cuts being determined as just explained, and $cunp$ will be the pattern for the other jack-ribs, the plumb-cut of which, where they join the arch ribs ced, cfb, etc., will be the line pn on one side of the rib, and the line rm on the other side, while a line drawn on the top or bottom of the rib joining the ends of the plumb-cut lines will mark the cheek cut, or bevel.



(a)

Fig. 26

37. In lathing the ribs of the passages, ordinary wooden lath may be used, but the pendentives and dome must have metallic lath so that they may be smoothly finished in plaster.

38. Niches.—Vaulted, groined, and domed passages, such as those just described, seldom occur except in monumental work, in which case the side walls of the passages are often broken by niches for the reception of pieces of statuary, vases, etc. Fig. 26 shows the construction of such a niche. The plan (*a*) shows the base acb, which is composed of $1\frac{1}{4}$-inch plank. Halved into the front edge of this base are the two studs a and b, shown in the elevation (*b*) at a' and b', extending from the base to the head-piece k, to which they are nailed. The studs n, o, p, etc. extend from the base to the plate l, on which rest the curved ribs n', o', p', giving the head of the niche a semidomical form. The front is closed by two quarter-circle ribs efg let in and nailed to the studs a' and b'. Bridging, or stiffeners, s are inserted between the ribs, and the whole is then lathed with wire or other metallic lath.

BRIDGEWAYS

39. A problem that sometimes confronts a designer is a **covered elevated passage, or bridgeway,** connecting adjacent buildings. The treatment of its structural features should be in harmony with that employed in the building proper.

The bridgeway shown in Fig. 27 connects the Administration Buildings of the International Correspondence Schools, Scranton, Pa. To relieve a horizontal beam line and the angularity at the wall connections, an arch rib is placed on each side, thus giving a pleasing outline to the soffit of the bridge. Corbeled springing blocks receive the end bearings of the arches and soften the appearance of an angle that would otherwise be disagreeable. These arches are kept well back of the lines of the bridge walls, and furnish an excellent opportunity to use a corbeled table as the base for the wall support—a characteristic of both buildings. This was effected by placing beams at right angles to the arches. These beams are 3 in. × 6 in. in section and have molded ends. As the floor is required to sustain heavy moving loads, the arches were designed and constructed with reference to architectural effect only.

40. Steel beams *c*, Fig. 28, 15 inches in height, are used to span the space between the buildings, and carry the weight of the superstructure. The walls are framed with sills *d*, caps *e*, and 2″ × 6″ studding. The roof is framed with rafters *f* and ties *g*, and is covered with narrow matched sheathing $1\frac{1}{8}$ inches thick. The cornice is cased, as at *h*, while at *i* is a collar, or architrave mold. In an exposed situation, such a member should be tongued into the fascia to prevent water from lodging behind it. A framed and paneled breast *k* is placed between the sill-course *j* and the cap of the corbeled table, the upper rail being tongued into the window sill. The panels are made of $\frac{7}{8}$-inch narrow matched lining put together with white-lead joints, the framing being $1\frac{3}{8}$ inches thick and the lower rail beveled to shed the water. Nailing

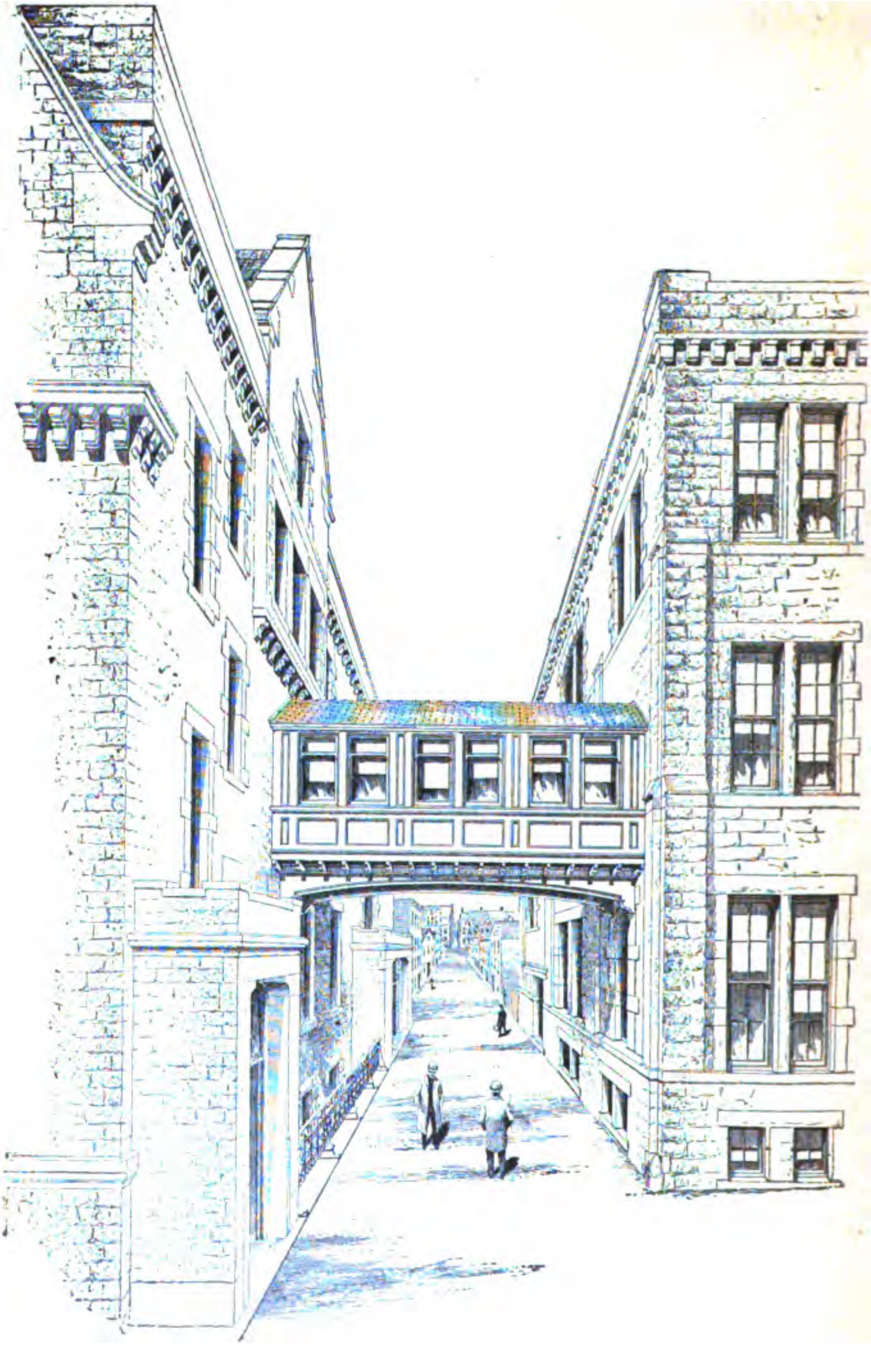


FIG. 27

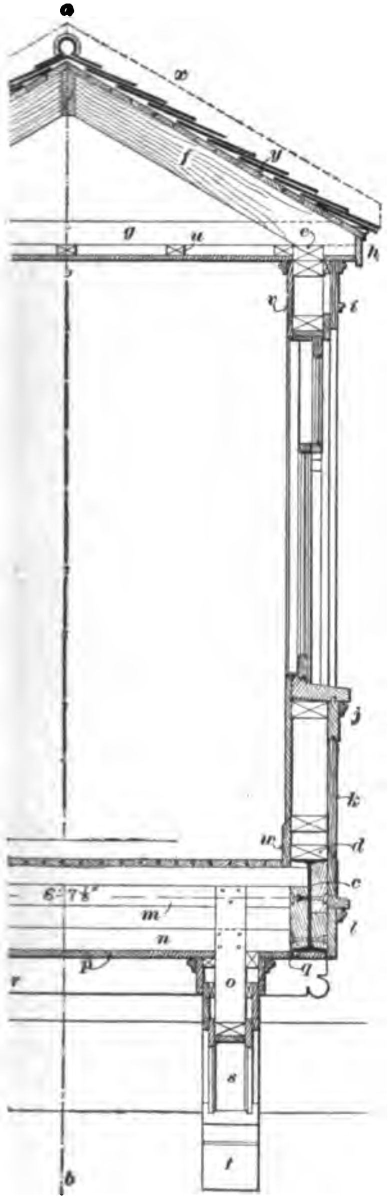


FIG. 28

cleats *m* are spiked to the 3-inch plank floor; to these are nailed the hangers *o*, which serve both as supports and as blocking for the arch casings. Light ceiling joists are nailed to the hangers for the attachment of the ceiling lining *p* and soffit *q*. The lining is matched and beaded between the arches, and runs parallel thereto. The soffit *q* is one board, which, being devoid of longitudinal lines, renders the corbel lines more prominent.

41. The interior walls and ceiling are lined with $\frac{7}{8}$-inch narrow matched-and-beaded material *v*, the ceiling lining being fixed to longitudinal furring strips *u*. The bead lines on walls and ceiling are made to run in line. The wall lining is cut to finish on the jamb lines of the window frames, the openings being finished with a $\frac{5}{8}$-inch molded sash stop, as shown. This treatment is lighter and simpler than that usually followed where a casing is planted on the surface of the lining. A continuous base *w*, $1\frac{1}{8}$ inches thick, is placed at the floor, and the upper edge is beveled to receive the end of the vertical lining. By this arrangement, the beaded joints can be kept clean—a result that cannot be attained when the lining is run down to the floor. Another objection to extending wall lining to the floor is that, when the floor is washed, more or less of the water is absorbed by the end wood, causing it to rot. The plank flooring, being run at right angles to the steel beams, is spiked to a plank bolted to these beams, while the finished flooring is laid diagonally, thus securing the greatest strength from the material employed. Quartered, or rift, flooring is used, so that under the wear of truck wheels the fibers will not curl up and sliver.

42. The roof sheathing is overlaid with heavy felt and is covered with terra-cotta shingle tile, the lap-jointed ridges being set in slater's elastic cement. A flat gutter $\frac{7}{8}$ inch deep and 4 inches wide is formed at the wall junctions, in order to avoid tilting the edges of the tiles. The gutter flashing of 6-pound lead passes up 4 inches on the face of the wall and is beaded and inserted 1 inch into a raglet, or groove, left in the joint between the lower brick filling and the upper stone ashlar.

STORE FRONTS

43. It frequently happens that a dwelling situated in the business part of a town has to be altered so that the first floor can be used for business purposes. In Fig. 29 (*a*) is shown an elevation of the first story of a brick dwelling of the Colonial style changed so that it can be used as a bank. At (*b*) is shown the plan, which is self-explanatory, the space inside the window can be utilized for the cashier's office.

This is a wooden store front, such as would be built in a village or small town where wooden construction is allowable, or in a city, outside of the fire limits. The general scheme is Colonial to conform with the rest of the building. The cornice is simple, but carefully studied in outline and proportion; it is enriched with a dentil course and plain, circular rosettes over each column.

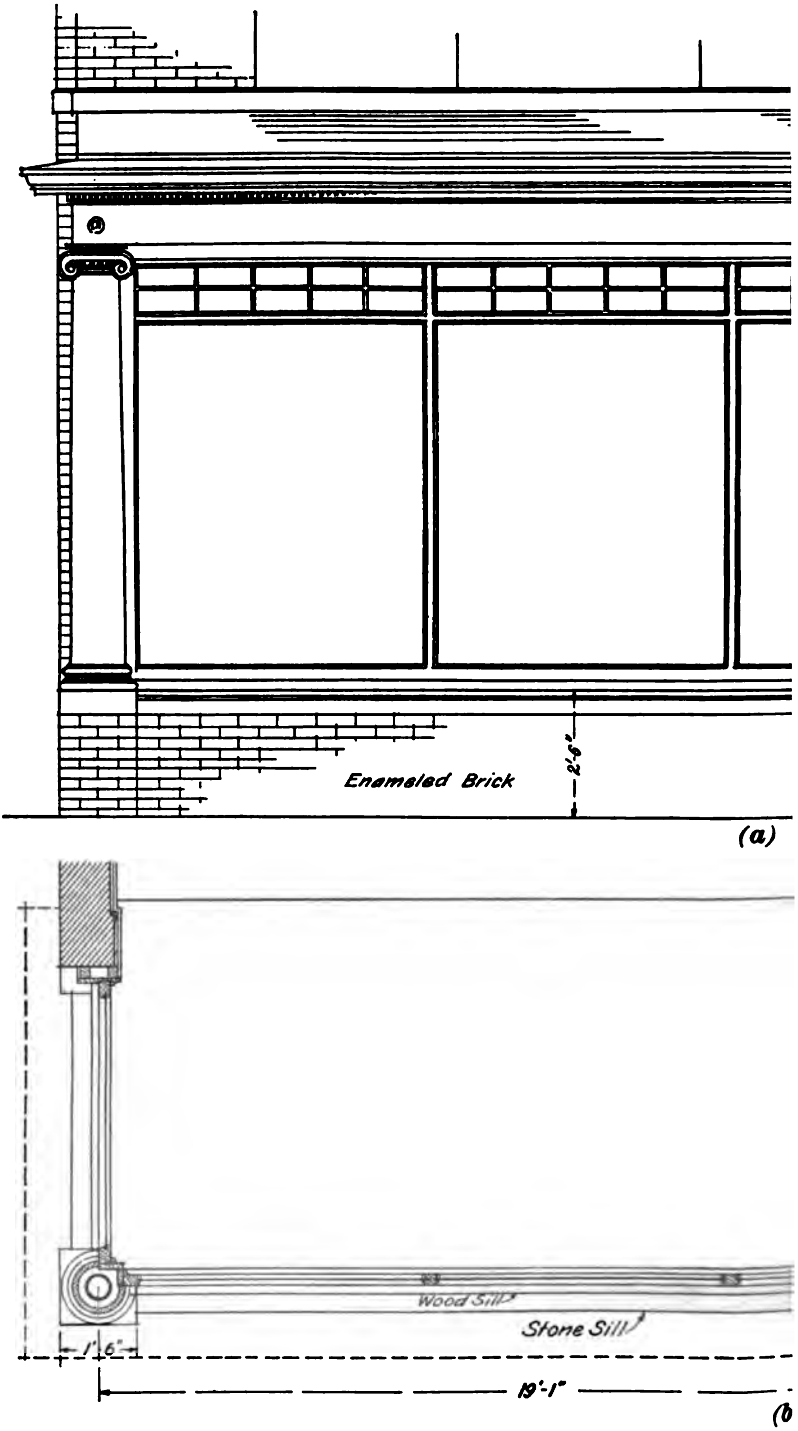
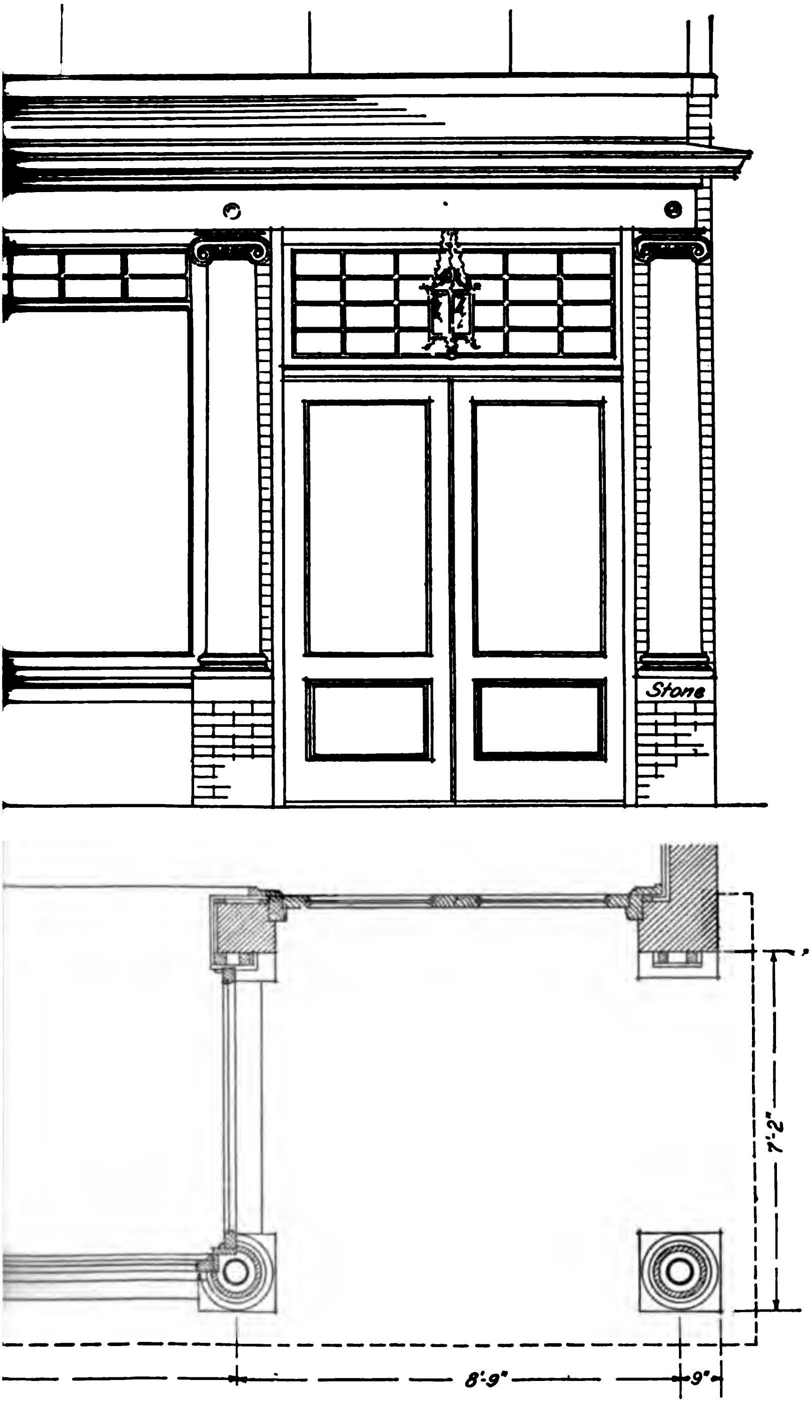
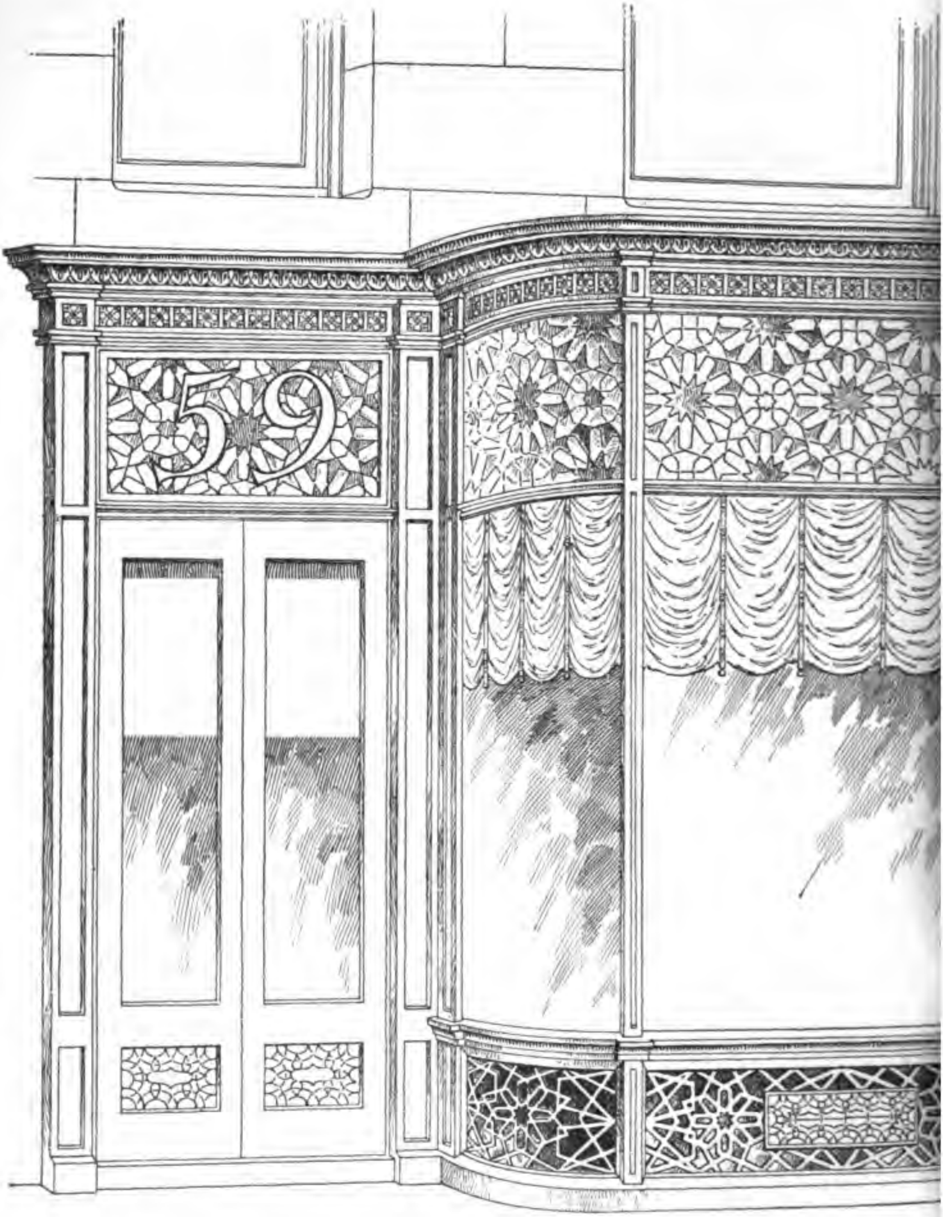
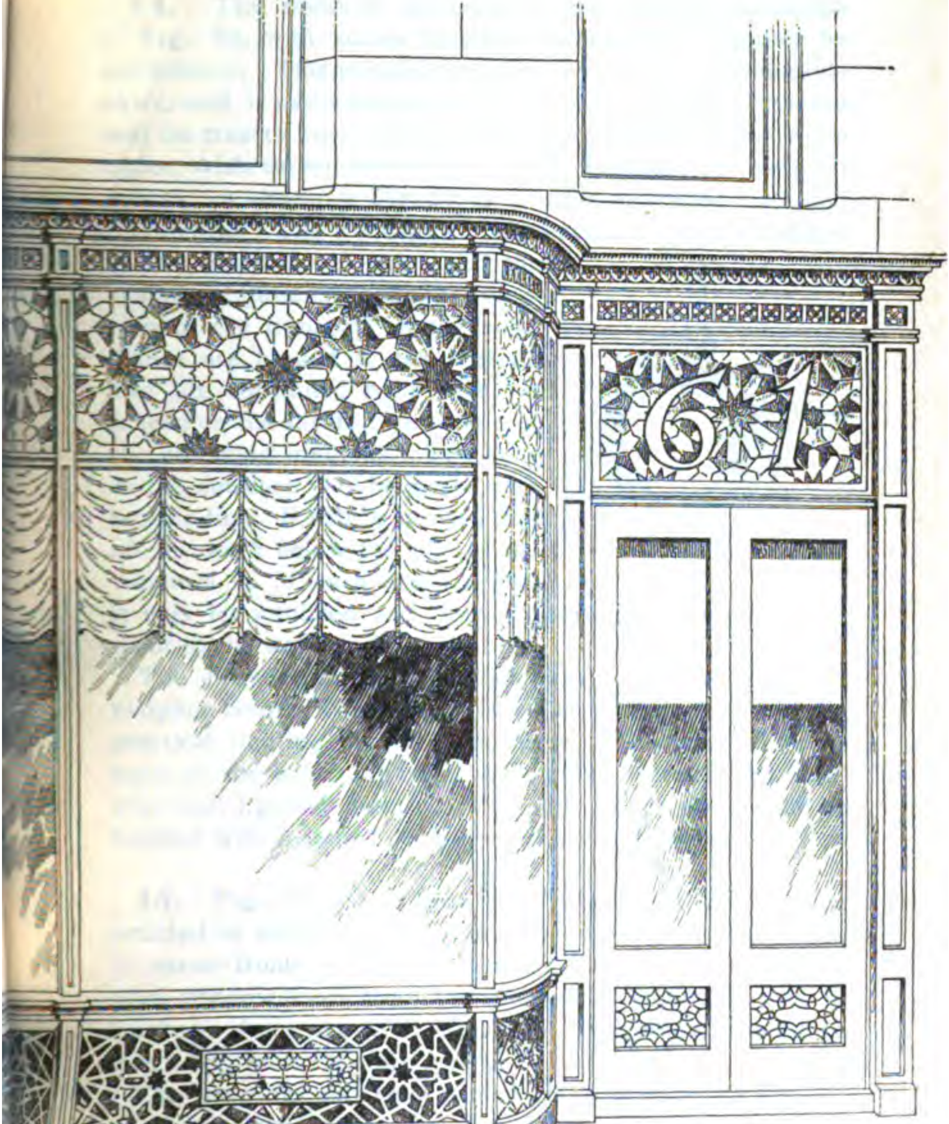


FIG.


Stone
7'-2"
8'-9"
9"



Fi


61

44. The shafts of the columns are built up, as shown in Fig. 30, with staves tongued and grooved together by machinery. This method furnishes a very rigid and durable shaft, and, if well executed, will always remain free of checks and be true to line. The columns are designed in the Ionic order, with carved white-pine caps. The base, or pedestal course, as shown in Fig. 29, is of white enameled brick and terra cotta. The woodwork of the exterior is painted white.

The glass is all plate, and the sashes are stationary, with the exception of the transoms of the front. These are hinged at the bottom, and are controlled by a sash lift placed on the inside face of one of the adjoining mullions. The floor of the entrance may be paved with mosaic tile. It will be noticed that all the work below the sills of the windows is of such material that it may be scrubbed and cleaned thoroughly without detriment to the woodwork.

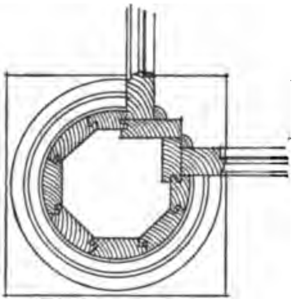


Fig. 30

The entrance is lighted by an old Colonial wrought-iron hanging lamp. This lamp is used more for effect than for practical lighting purposes, however. The interior woodwork of the bank may be of mahogany, with nickeled hardware and lighting fixtures. The soffit of the porch may be finished with matched ceiling or be paneled, as desired.

45. Figs. 31 and 32 show store fronts that may be constructed of wood, cast iron, sheet copper, or galvanized iron. In these fronts, it will be noticed that the height of the show-window floors from the sidewalk is much less than in the bank front shown in Fig. 29. The height should be about 18 inches for store fronts.

The transoms may be of leaded glass, as shown in Fig. 31, of prism glass, as shown in Fig. 32, or of clear plate glass, the same as the large windows. Prism glass should be used where the light is not good and needs improving. As shown in Fig. 31, the sheets of plate glass are joined by mullions. Sometimes, however, where mullions are not required for the support of work above, the glass is butted together and fastened by clips, as shown in Fig. 32. This presents a very good appearance and gives an unobstructed view of the contents of the window from all points.

ORNAMENTAL SHINGLING

46. Cut shingles are used both on the sides and on the roofs of buildings. On roofs they may be arranged in a diaper effect or laid in bands, while on the sides they may be laid in a diaper pattern or in bands, or rows. They are usually applied to such places as the triangular portions of end walls above the eaves-line termed *gables*, to the small gables, or *gablets*, of dormers and porches, and in filling in spandrels and panels. Structural features such as posts, beams, and brackets should never be reproduced in shingling.

An example of treating the shingles over the head of a semicircular opening is shown in Fig. 33, which shows a small window with splayed sides and head and crowned with a series of voussoirs in arch effect.

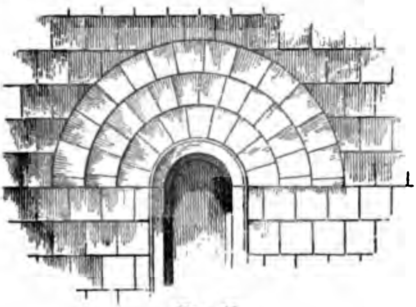


FIG. 33

47. In Fig. 34 is shown a portion of the side elevation of a country house that is to have for its chief feature a covering of cut, or ornamental, shingles. The porch shows a closed balustrade at *a*, with cut shingles of the geometric class, simple and uniform in design. The rails, pedestals, columns, etc. all stand out structurally, while the shingled portion is merely a filling. It will be observed that the columns do not rest on a base of shingles. This arrangement, though sometimes followed, does not give a feeling of

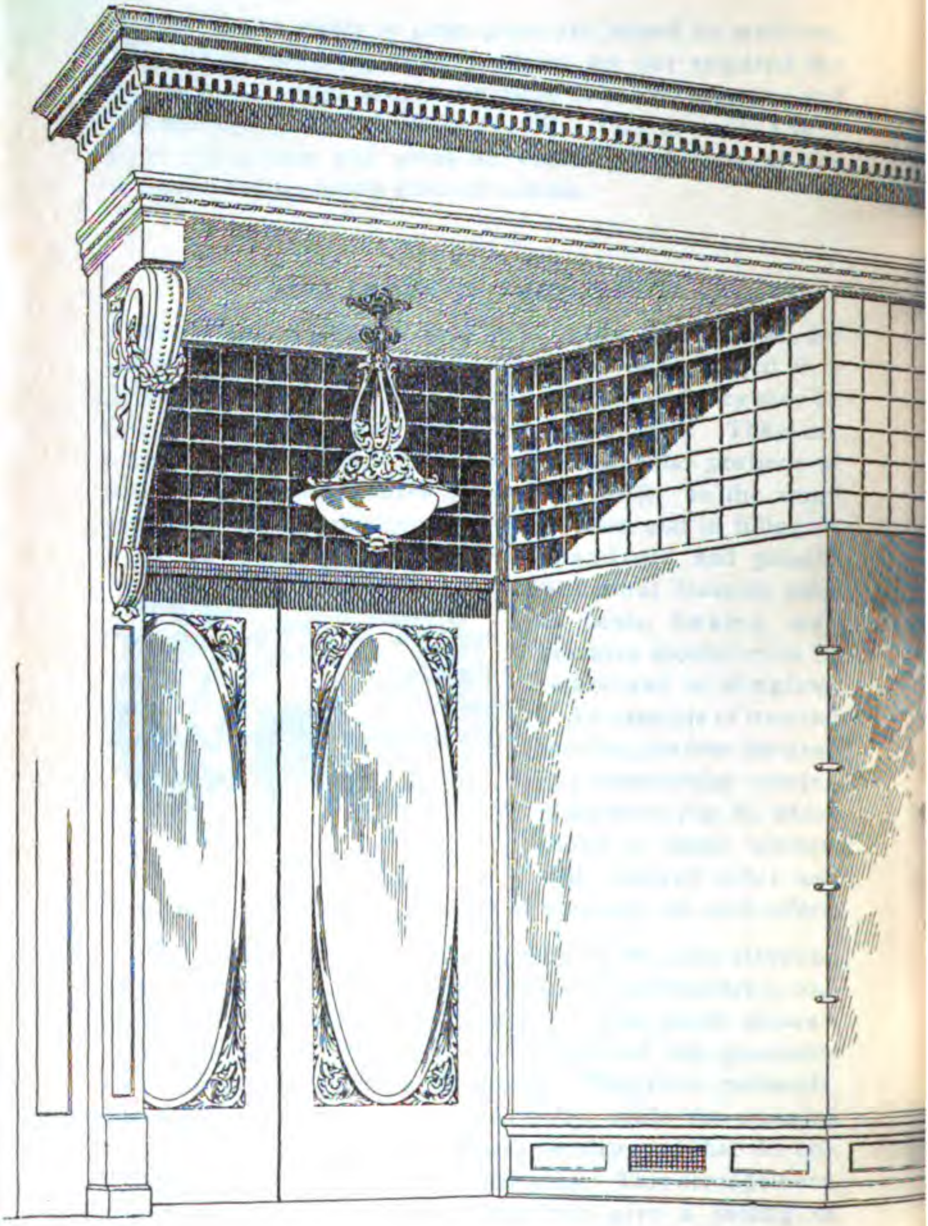
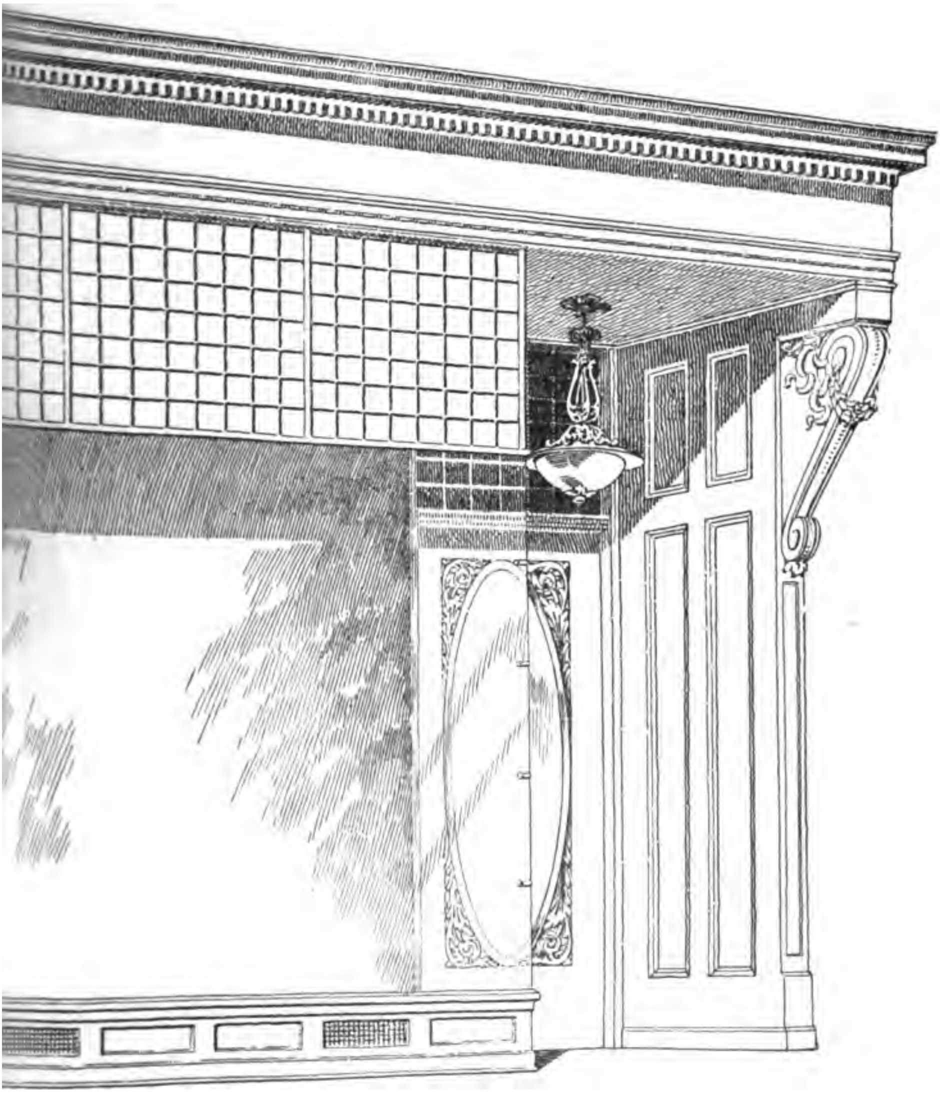


Fig.



stability, while in the example shown the roof and cornice have their supports clearly defined from the brick foundation up.

To cut and lay the balustrade shingles, select two widths, one 2 inches and the other 4 inches. Take the 4-inch shingle, lay off on each lower corner an angle of 45°, measured either up the side or across the butt 1 inch from the corner, and saw off these corners. When the required number of shingles has been cut, take square-butt shingles and start with them, laying the first row along the length of the rail. Measure up 1 inch, and at this height above the rail lay a 2-inch shingle in the lower left-hand corner, and next to it lay a 4-inch cut shingle. Start the second row with three-quarters of a 4-inch shingle, and continue until completed.

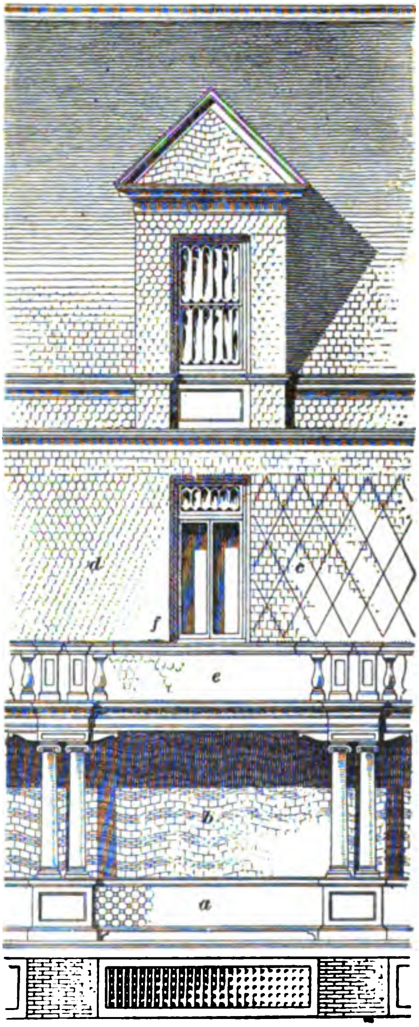


FIG. 34

48. The first-story walls, as shown at *b*, are covered with shingles cut to produce slightly wavy lines, and so arranged that they come in courses of two wide ones followed by three narrow ones. This arrangement in no way suggests the coursing of stone, but still gives length and scale to the house, and is sufficiently plain not to detract from the upper-story treatment.

To lay the first-story shingles, make a templet out of any convenient thin piece of wood 3 feet long and 8 inches wide. Measure up 4 inches from the side of the board at each end, representing the depth of the gauge, and from these points draw the curve freehand, letting the center of the full part of the curve just touch the side of the board at the center. When the desired curve is found, take a spline and draw in the finished curve. Cut the templet out on this line, and cut all the shingles from it.

For a starting course, lay a row of plain-butt shingles from end to end of the surface to be covered. Then take the chalk line, and in the usual manner snap off the gauge line; lay the first shingle of the waved line with the shortest side against the corner board and just touching the gauge line. Now set the center shingle with its butt flush with the plain butt, or 4 inches below the first shingle of the wave, and fill in with the others; this will insure a uniform job.

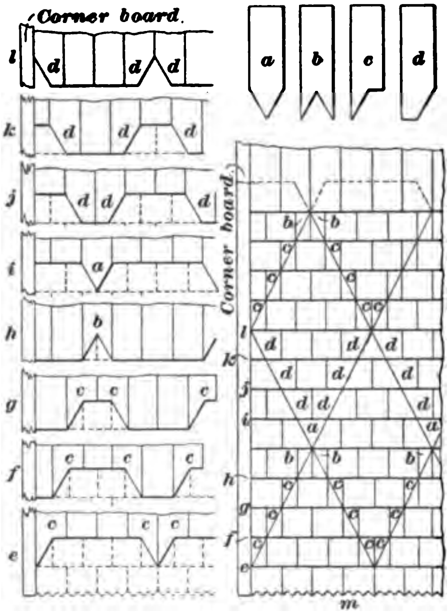


FIG. 35

49. The second story may be finished either as shown at *c* or as shown at *d*, Fig. 34. The belt course *e* may be of the same pattern as the closed balustrade of the porch. The butts *f* are finished "saw tooth," which allows the water to drip off quickly, and at the same time gives a neat finish. The diaper effect *c* is produced in every eighth course alternately, making a very neat finish for a shingle house, while the pattern is large enough to give it character. The shingles are placed in much the same manner as in common work and are laid 4 inches to the weather. There are four patterns necessary, *a*, *b*, *c*, and *d*, Fig. 35—*a* for a starter, *b* for a finisher, and *c* and *d* for starters and finishers, as well as for the shingles forming the sides of the diaper.

To lay the side *c*, Fig. 34, start with a course of square-butt shingles. Next lay a saw-tooth course with the points flush with the first course; over these, at the usual gauge, lay another square-butt course. Against the corner board at the left, place a shingle *c*, Fig. 35, with the point flush with the butt of the last square-butt course. Next to it lay two square-butt shingles, even with the right-hand corner of *c*; then lay another *c* reversed, and complete the row, which will appear as at *e*, Fig. 35.

Lay half of a square-butt shingle against the corner board, with the butt flush with the two square butts in the row just laid; set a *c* against it, then a square butt. then a *c* reversed, and next a square butt. This row will appear as at *f*. Then lay one square butt against the corner board; next to it lay a *c*, then a *c* reversed, and then a square butt, which will appear as at *g*, Fig. 35. Next lay a half square butt against the corner board, next to it a whole square butt, and against that a finisher *b*, which will appear as at *h*. Now lay a course of square butts through from end to end. Start the next course with a half square butt, then a whole one, and next to it the diaper starter *a*, as at *i*. In the next course, start with a whole square butt, next to it a *d*, then a *d* reversed, and then a square butt, as at *j*. In the next course, start with a half square butt, then a *d*, then one square butt, and next a *d* reversed, as at *k*. In the next course, start with a *d*, next to it two square butts, and then a *d* reversed, as shown at *l*. Start a continuous square-butt course and continue the next diaper, starting as in the first case. The completed work will appear as at *m*.

The side *d*, Fig. 34, and the shingles on the dormer are all laid in the usual manner and need no description.

50. In Fig. 36 are shown several methods of laying cut shingles, and one of laying square butts. The latter is a very neat and pleasing way of laying shingles; besides, it has the advantages of making them last longer and taking less to cover a given surface.

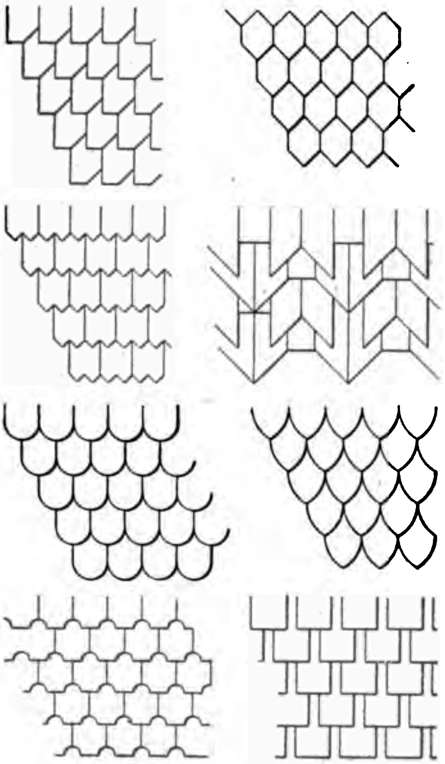


Fig. 36

FLAGSTAFFS

51. Strange as it may seem, it is as necessary to profile a flagstaff carefully as it is to profile an architectural column. The curve of the shaft of a column is called the **entasis**, and the method of profiling this curve is also of service to the flagstaff designer. Two converging straight lines in any elevated structure have always the appearance of concave ones, giving a weakened effect to the outline of the mass. With flagstaffs extending from 30 to 60 feet above the highest point of the roof, the following rule has been found to give satisfactory dimensions:

Rule.—*The diameter, at the base of a flagstaff, where it passes through the roof, should be about one-fiftieth of the* *altitude, and the diameter at the apex should be equal to one-half of the lower diameter.*

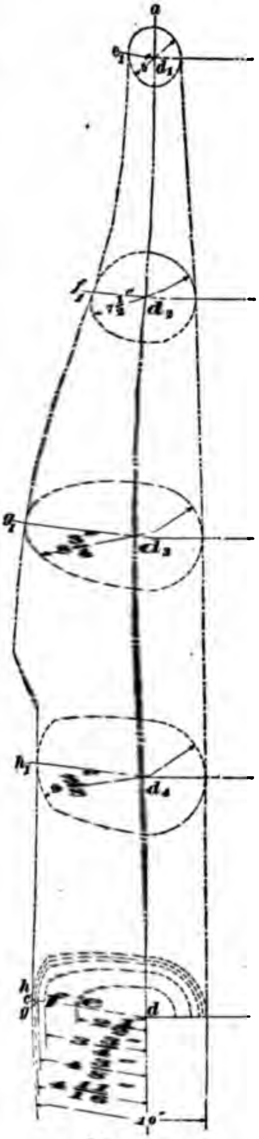


FIG. 37

For example, if a flagstaff is to be 41 feet 8 inches, or 500 inches, in length, its diameter should be one-fiftieth of this amount, or 10 inches, while its diameter at the apex should be 5 inches. The diameter at the base and the apex having been determined, it will then be necessary to profile the shaft by some accepted rule.

The method followed by a veteran mast maker is as follows: Make the upper diameter equal to one-half of the lower.

Draw a center line ad through the shaft, as shown in Fig. 37. Divide cd, the lower semidiameter, as follows: From d mark a point equal to one-fourth of the lower diameter, as de. Divide the remaining distance ec into two equal parts, as at f, and divide the distance cf into two equal parts, as at g, and the distance cg into two equal parts, as at h. Divide the vertical height of the shaft into four equal parts by horizontal lines; transfer the distance de to d_1e_1, df to d_2f_1, dg to d_3g_1, and dh to d_4h_1. Then, through the points marked will pass the curve of the entasis.

52. In Fig. 38 are shown the metallic finial at the top of the shaft and the flashing to make the pole water-tight where it passes through the roof of a cupola. These parts are drawn to an enlarged scale, such as would occur in the working drawings. The ball a, in (a) is 10 inches in diameter, of soft-rolled copper, spun down to about 18 ounces per superficial foot, and is sweated to the socket b. The stem c

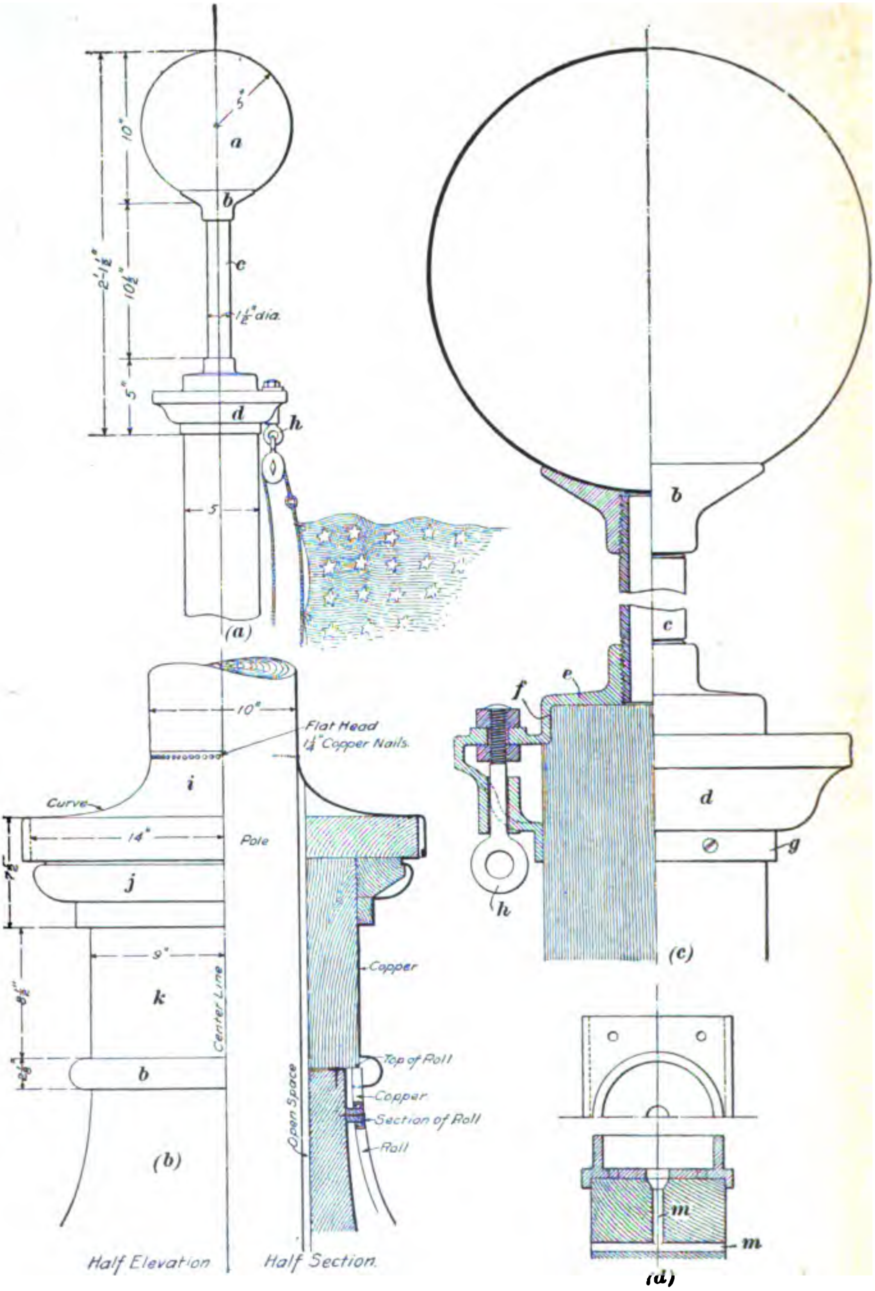
5"
10"
2'-1½"
10½"
5"
a
b
c
1½" dia.
d
h
5
(a)
10"
Flat Head
1¼" Copper Nails.
i
Curve
14"
Pole
7½"
j
9"
8½"
k
Center Line
2⅝"
b
(b)
Copper
Top of Roll
Copper
Section of Roll
Roll
Open Space
Half Elevation
Half Section.
b
c
e
f
d
g
h
(c)
m
m
(d)

FIG. 28

is a bronze tube $1\frac{1}{2}$ inches in diameter, while the cap *d* is of cast bronze. The stem *c* is threaded, and passes into the socket *b* and cap *d*, as shown in (*c*). The cover *e* protects the upper end of the pole and prevents water from passing into the fiber tubes. The flange *f*, being tightly fitted to the pole, keeps the stem of the finial in a vertical position, while heavy brass screws attach the lower flange *g* to the pole. An eyebolt *h* is secured to the cap, and is firmly held in position with a nut and lock-nut. The end of the eyebolt is also riveted in place. From the eyebolt is suspended a brass or lignum-vitæ block, having a 3-inch brass pulley and pin.

The pulley block is attached to the eyebolt with a detachable link, as shown in Fig. 39. This link is rigidly clasped by a bronze bolt to the eyebolt *h*, Fig. 38 (*c*), and the link, being set at an angle, prevents the pulley block from swinging and chafing the flagstaff.

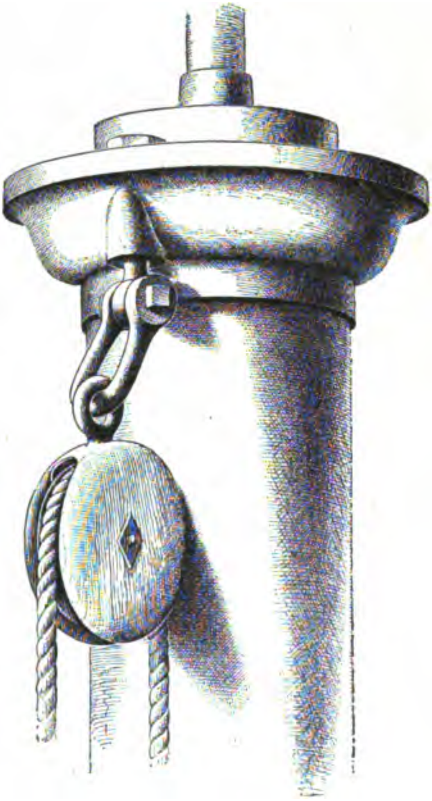


FIG. 39

In Fig. 38 (*b*) is shown a half section of the apex of the dome of the cupola, through which the flagstaff passes. At *i* is a capped flashing of 8-pound lead, arranged in such a manner that the pole may sway without straining the connection. The bed mold, frieze, and collar band, as at *j*, *k*, and *b*, respectively, are of cold-rolled copper, as are also the

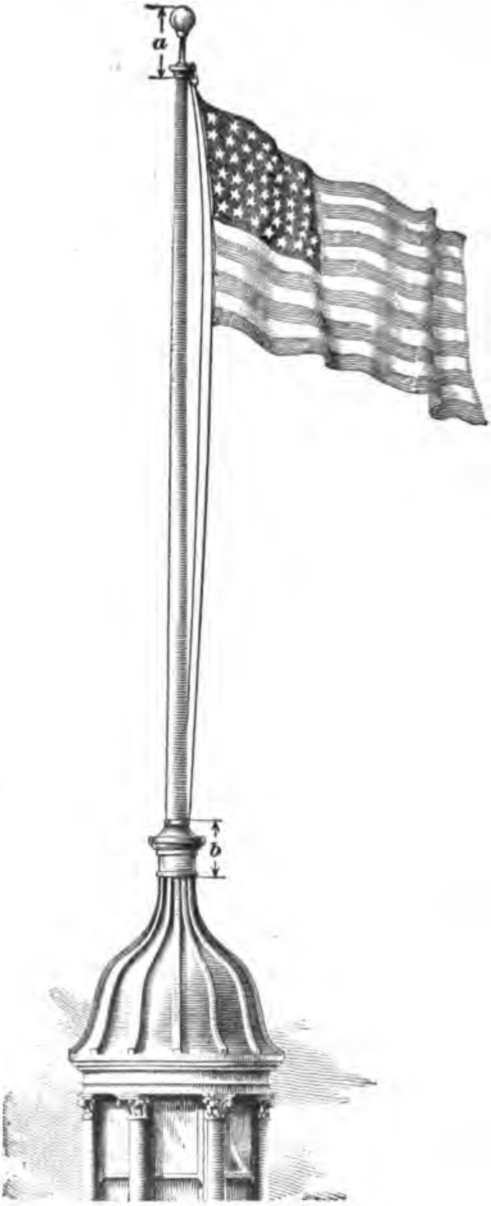


FIG. 40

roll caps of the dome. The panels of the dome between the rolls are of soft-rolled copper, which is sufficiently flexible to obtain the desired curvature.

In Fig. 38 (*d*) is shown a half plan and section of a cast-iron socket plate, in which rests the base of the flagstaff. In order that any sap precipitated from the body of the pole may not be confined in the socket, causing fermentation and subsequent decay of the wood, a hole is formed in the plate, and 1-inch vertical and transverse holes, as at *m*, *m*, are bored through the beam on which rests the flagstaff.

53. Flagstaffs may be constructed of spruce, Norway or Michigan pine, Georgia pine, or Oregon pine. The latter is considered to be preferable, and, where the entire sapwood is removed by cutting the flagstaff out of the heart of a large trunk, a durable pole is obtained. The pole should be painted with at least four coats of geniune white lead. The ball of the finial should be prepared with oil size and then gilded with XXXX gold leaf.

Halyards should be at least ½ inch in diameter, and be of waterproof, braided cotton or, preferably, Italian hemp.

The appearance of the flagstaff made according to the drawings shown in Figs. 37 and 38 is shown in Fig. 40.

FRAMING A HAY BARN

54. In the construction of gambrel-roof hay barns, where it is desired to leave a wide central space so that the rack wagon may be drawn into the barn and unloaded, or loaded from the mow on each side, the following two systems of framing will be found to meet the requirements in barns about 34 feet in width. The gambrel form of roof is used to gain a large interior area.

55. In Fig. 41, bents *d*, *g*, *f* are set on the sill *h*; these bents support the plates at *g* and *b*. The floor joists are spiked to the toe of the bent at *h*, and as these joists reach across the building, they effectively tie the toes together. Considering the frame formed by the pieces *c*, *d*, *e*, *f*, *g* as hinged at *b* and *h*, it is evident that the thrust *b*, caused by the rafters *i*, *i* tending to straighten out under the vertical load, will revolve and cause the frame or members *c*, *d*, *e*, *f*, *g*, to turn outwards about the point *h*. This frame must therefore be held in position; and to do this, the brace *j* must be introduced. The force in this brace will be tensile, which will exert an upward pull on the joist *k*. This force will tend to produce bending in the joist; but the weight of the flooring and load will more than counteract this tendency, as will also the weight of the roof on the rafters *c*.

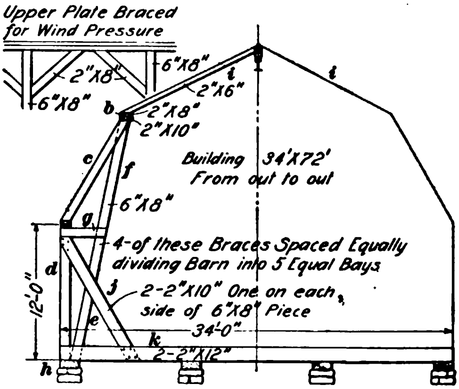

Upper Plate Braced for Wind Pressure
2"X8"
6"X8"
6"X8"
b
i
2"X6"
2"X8"
2"X10"
i
c
f
Building 34'X72' From out to out
6"X8"
g
4-of these Braces Spaced Equally dividing Barn into 5 Equal Bays
d
12'-0"
j
2-2"X10" One on each side of 6"X8" Piece
e
34'-0"
k
2-2"X12"
h

FIG. 41

56. Another and more stable form of construction is shown in Fig. 42. Here, a post *b* stands vertically and directly supports the plate *d*, on which rest the rafters *e*. The bents are tied and braced, as shown, and are also held together by the floor joists. The bents are six in number, including the end ones, and are spaced about 14 feet 5 inches apart from center to center.

The gable ends can be constructed as shown in Fig. 43 or with a tie or collar beam, in which case the construction shown in Fig. 42 need not be followed at these points. The sills are continuous the full length of the building, and in addition to supporting the upright posts of the bents, they form a bearing for the floor joists. The ends of the rafters shown in Fig. 42 are notched and fitted to the upper and lower roof plates, thus making the work secure at these places and eliminating all danger of the rafters slipping or pushing outwards under direct compressive stress. The edges of the rafters *c*, *c* should be somewhat above the edge *d* of the plate, so that, should the rafters shrink considerably, the sheathing will still have a bearing on them and not on the edge *d* of the plate. Longitudinal bracing should be introduced to stiffen the frame, as shown at *a*, *a*, Fig. 43. If the sides of the barn are shingled or weather-boarded, these braces can be done away with entirely by running the sheathing diagonally, thus adopting the balloon-frame type of construction.

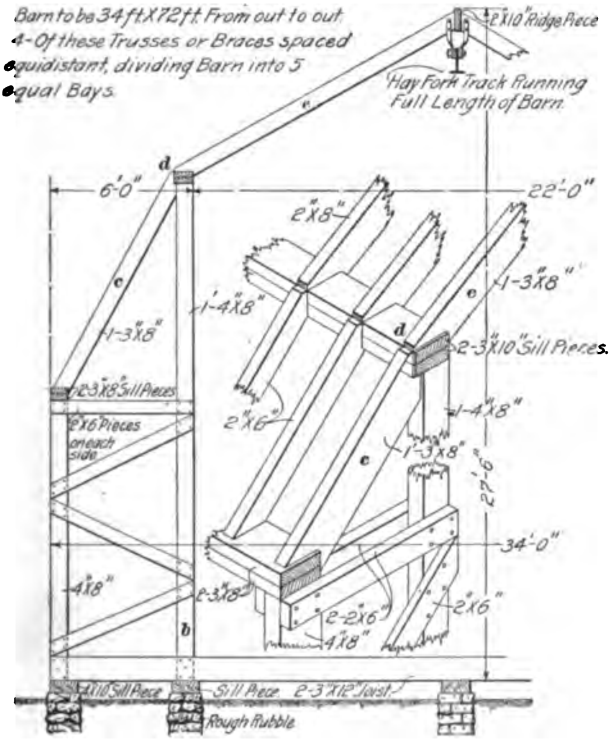


Fig. 42

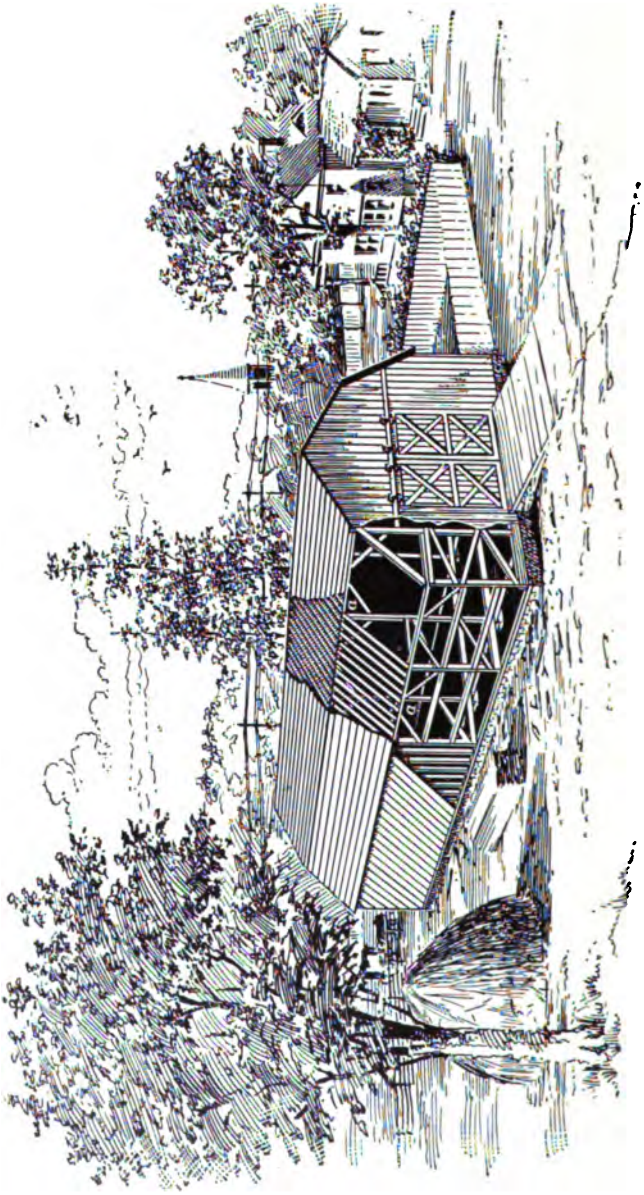


FIG. 43

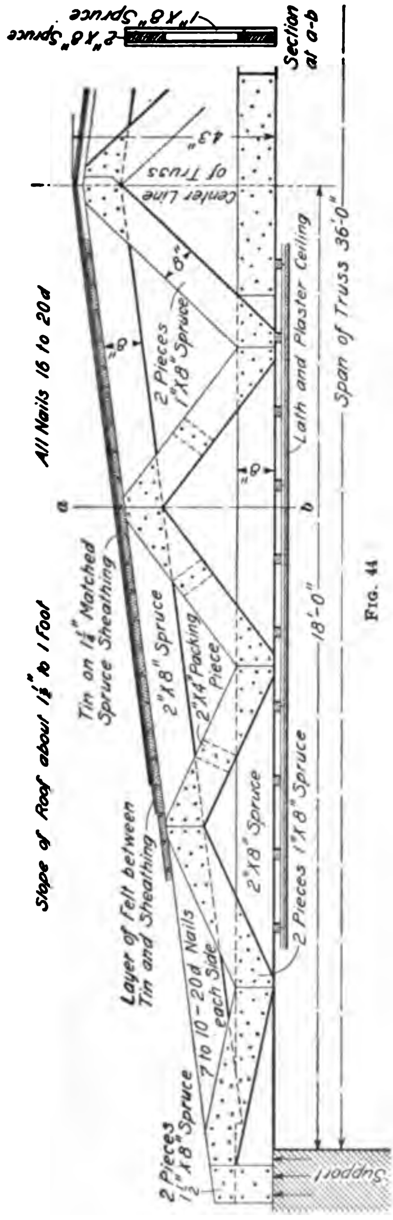


FIG. 44

LATTICE BRACING

57. Fig. 44 shows in detail a system of trussing, or bracing, the rafters in conjunction with the ceiling joists for a roof having a long span and a low pitch. The rafters and joists are to be 2 in. × 8 in. and of a good quality of spruce or hemlock. The lattice braces are composed of 1″ × 8″ spruce, and are placed in pairs, one on each side of the main members, to which they are spiked. The spiking, or nailing, should be well done, especially in the lattice members near the supports of the rafters, as the greatest stress is on these members. It will be necessary to splice the tie-member at the center of the span, as difficulty may be experienced in obtaining a 2″ × 8″ piece of sufficient length. For securing the splice, two fish-plates of 1″ × 8″ spruce are used; these are well spiked on each side of the 2″ × 8″ ceiling joists. Two iron dogs, well driven in, should be used to further secure the splice. The roof should be covered with $1\frac{1}{4}'' \times 6''$ tongued-and-grooved surfaced spruce and a layer of felt, on which the tin is laid. The furring strips for the lath and plaster of the ceiling should be placed at 16 inches on centers. All the necessary details of construction are shown in the figure, so that further explanation is not required.

HALF-TIMBER WORK

58. Figs. 45, 46, and 47 illustrate a very picturesque method of wall construction, called **half-timber work.**

This method was very popular throughout medieval Europe and many beautiful and interesting structures of this type are still extant, and attest the skill and taste of our worthy ancestors. These illustrations give three different views of the Leicester Hospital, at Warwick, England, endowed by the Earl of Leicester, a favorite of Queen Elizabeth, as a home for venerable English veterans. This is probably as good an example of old half-timber work as can be found.

In this work, the timber of the exterior walls was structural, as in barn-framing, and of course ran clear through the wall, the spaces between the timbers being filled with brick, on the outer surface of which was placed one or more coats of plaster, finished smooth or rough-cast. The inner surface was lathed and plastered in the usual way.

Fig. 48 shows a design for a modest little cottage, typical of the earlier work, but constructed on a cheaper scale. The first story is constructed with common brick covered with a coat of plaster having a "slap-dash" or rough-cast finish coat. The upper-story walls are formed with the usual balloon framing and sheathing and the lines of the old style framing are imitated by attaching casings to the wall sheathing and finishing the panels with plaster applied to wood or metal lathing.

59. In Figs. 49 and 50 are shown details of two methods of constructing the half-timber work over the porch. Probably that shown in Fig. 49 (here the first or first two coats

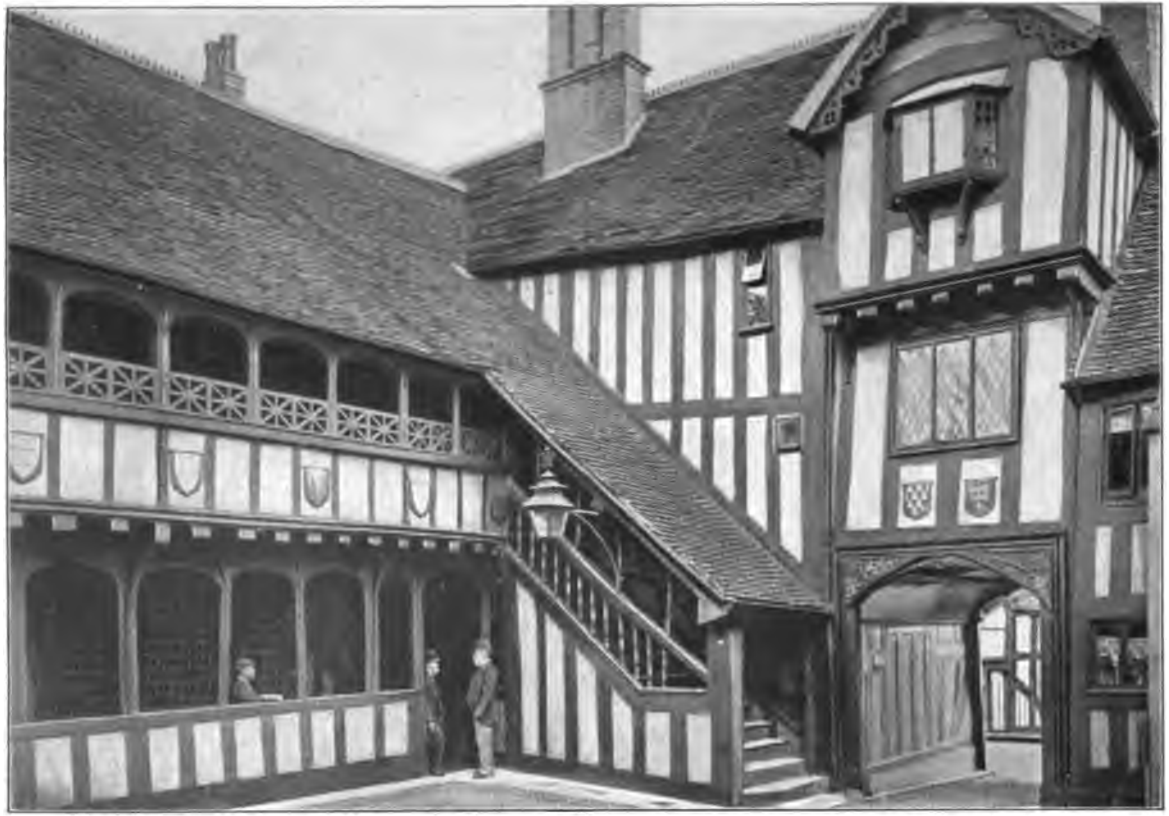


FIG. 45

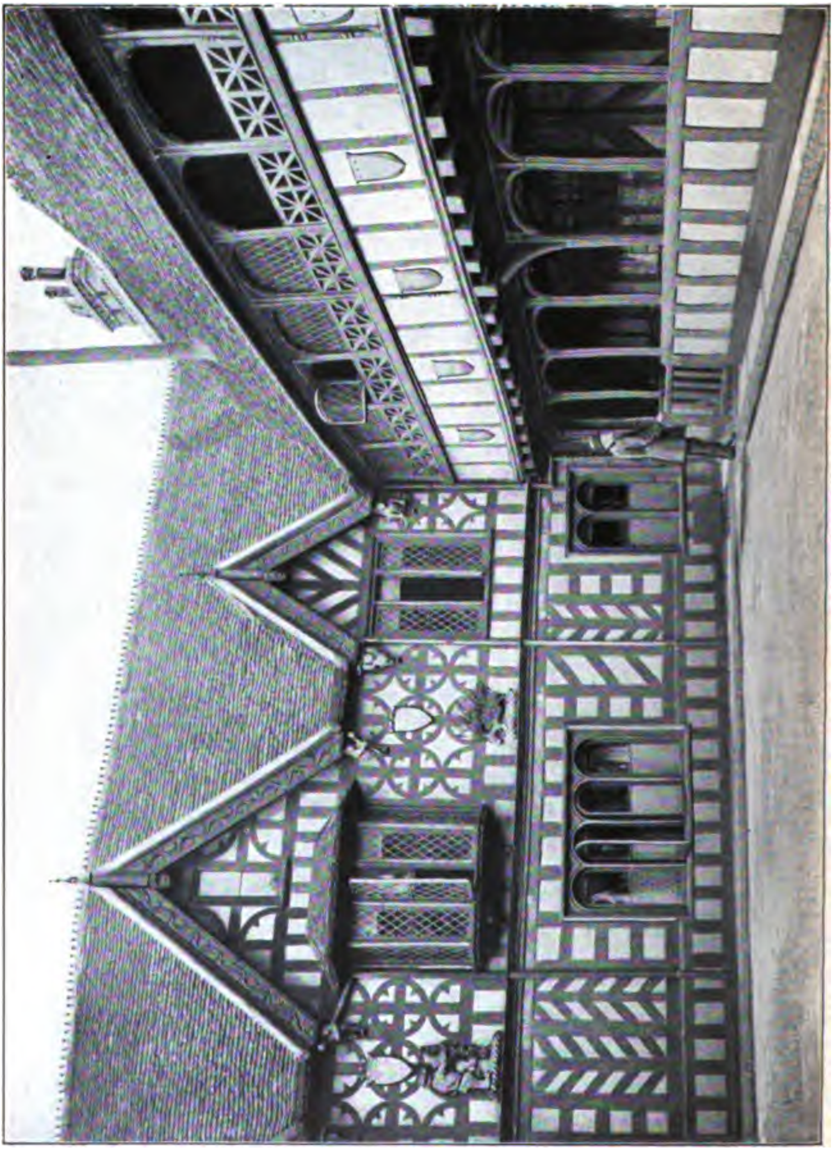


FIG. 46

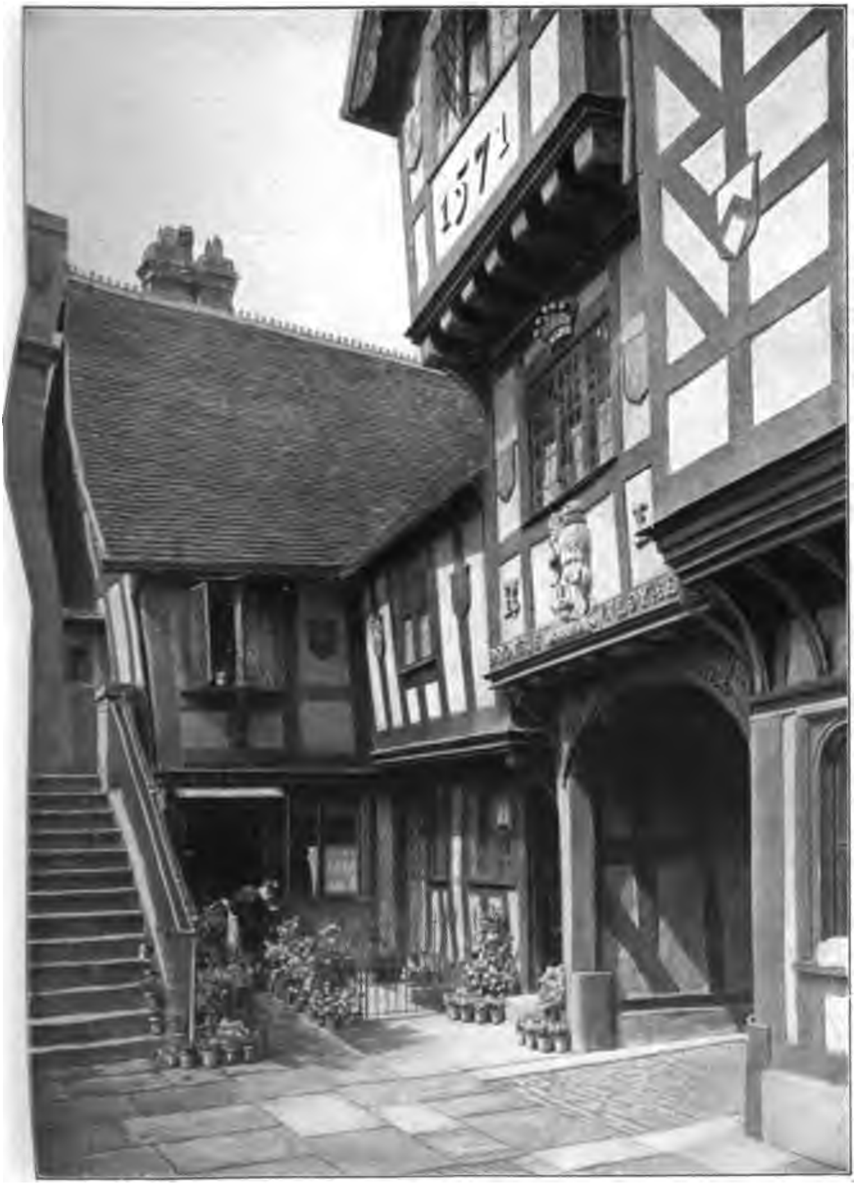


FIG. 47

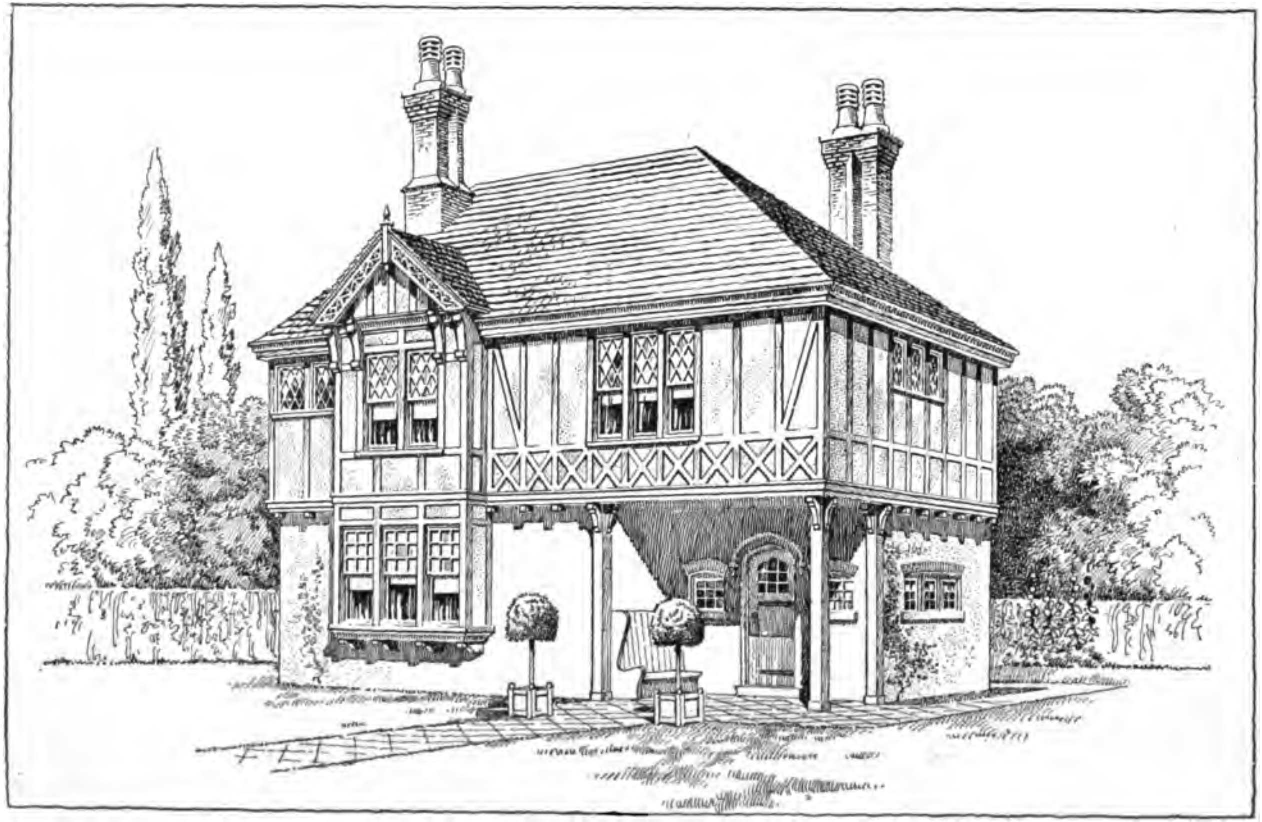


FIG. 48

are placed before the battens are fastened, followed by the last coat) would be the tighter, as the opening of the joint between the plaster and the timber is less liable to result in the penetration of water into the wall behind than in the

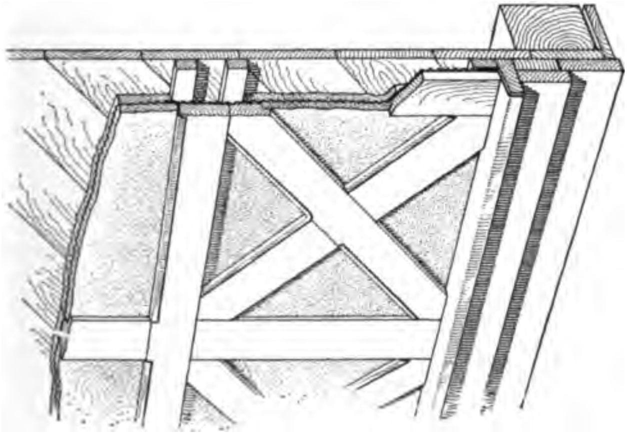


FIG. 50

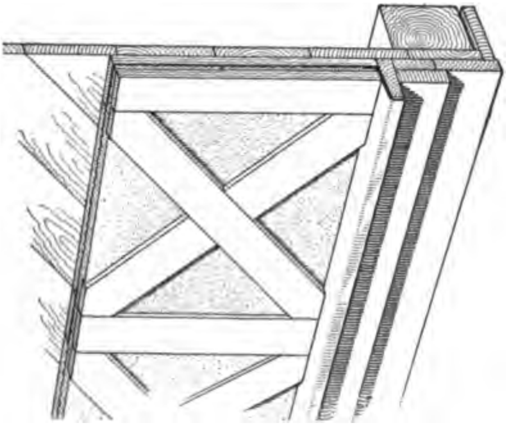


FIG. 49

construction shown in Fig. 50. If it is possible to delay the work to such an extent, this timber work, after being put in place, should be allowed to stand for several months before the plaster is applied. By doing this, the greater part of the shrinkage in the half-timber work will have taken place by the time the plastering is done, and the opening of the joint will be reduced to a minimum. An addition to the cement mortar of a proportion of lime putty will make it more plastic and elastic.

When metal lathing is used, a waterproof coating should be applied to the plaster to prevent the corrosion of the metal caused by the penetration of rainwater.

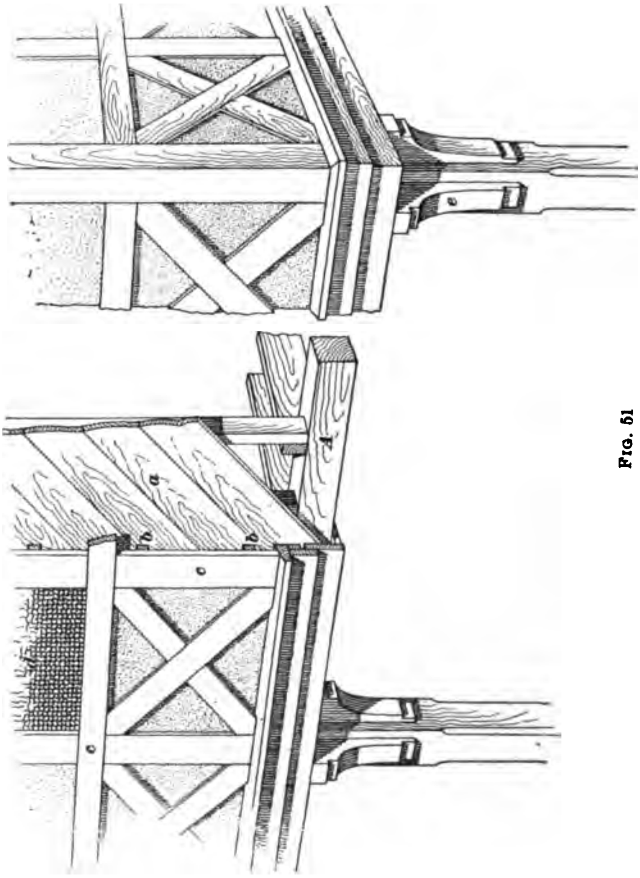


Fig. 51

The woods suitable for this kind of work are oak, cypress, yellow pine, and chestnut.

60. Fig. 51 shows the general construction of the work over the porch. The brackets *e* are housed into the posts. The beam *A* carries the floor joists and frame wall; *a* is the sheathing, to which the furring strips *b* are attached, and *c*, *c* the battens or casings. The barge board of the gable is shown in Fig. 52—in elevation at (*a*) and in section at (*b*).

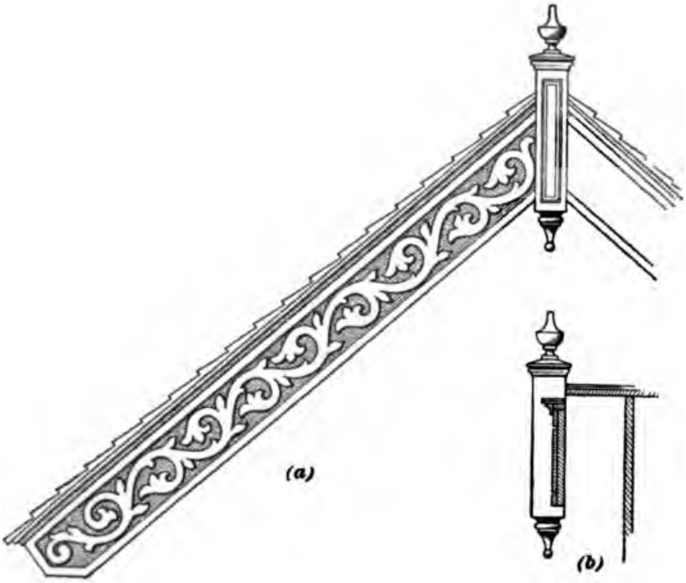


FIG. 52

In this case, the ornament is carved out of white pine, bedded in thick, white-lead paint, and nailed to the face of the barge board. In many cases a pattern is formed by piercing this board instead of applying the ornament 'as in this instance.

MECHANICS OF CARPENTRY

POSTS, BEAMS, AND JOISTS

STRENGTH OF POSTS

1. Long and Short Posts.—Posts are divided into two classes—*long posts* and *short posts*. A **long post** is one having a length greater than ten times the least thickness of its cross-section; or, in other words, a post 10 inches square, or 10 inches in diameter, or 10 in. × 12 in., as the case may be, and 101 inches in length, is a long post, because its length (101 inches) is greater than ten times the least thickness of its cross-section; that is, greater than $10 \times 10 = 100$ inches. A **short post** is one having a length less than ten times the least thickness of its cross-section. An $8'' \times 10''$ post, 6 feet long, is a short post, because its length ($6 \times 12 = 72$ inches) is less than ten times the least diameter of its cross-section; that is, less than $10 \times 8 = 80$ inches.

2. Safe Loading of Short Posts.—The safe working load of a short post is found by multiplying the area of the section by the safe compressive strength per square inch, which is given in Table I. This result is not the load that will break the post, but the *safe load;* that is, the load that the post can be designed to withstand in a building. It will be noticed in Table I that the varieties of woods have different strengths when used as posts.

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TABLE I

STRENGTH OF POSTS AND BEAMS

Kind of Timber	Safe Compressive Strength per Square Inch Pounds	Coefficient of Strength for Beams *k*	Coefficient of Strength for Flitched Beam *r*
White oak	900	16,000	9,710
White pine	700	10,700	8,828
Southern long-leaved, or Georgia, yellow pine	1,000	18,700	15,007
Douglas, Oregon, or yellow fir	1,200	17,300	12,359
Washington fir or pine (red fir)		13,300	
Northern, or short-leaved, yellow pine	800	16,000	10,593
Red pine	800	13,300	10,593
Norway pine	800	10,700	10,593
Canadian (Ottawa) white pine	1,000		
Canadian (Ontario red) pine	1,000	13,300	12,359
Spruce and eastern fir	800	10,700	10,593
Hemlock	800	9,300	7,945
Cypress	800	13,300	7,945
Cedar	800	13,300	6,179
Chestnut	1,000	13,300	8,828
California redwood	800	12,000	6,179
California spruce	800	13,300	10,593

Example 1.—What safe load will a Georgia yellow-pine post carry that is 4 in. × 6 in. and 3 feet long?

Solution.—The area of the post is 4 in. × 6 in = 24 sq. in. Referring to Table I, it will be found that the safe strength per square inch for Southern long-leaved, or Georgia, yellow pine is 1,000 lb. Therefore, 24 × 1,000 = 24,000 lb., which is the safe working load that the post will carry. If a heavier load than this is put on, the post is liable to break, while if a lighter load is employed, the post is stronger than necessary. Ans.

Example 2.—Suppose that the foregoing post is made of hemlock instead of Georgia yellow pine; how much will it carry?

Solution.—The area of the post is the same as before, namely, 24 sq. in. As given in Table I, the safe strength per square inch for hemlock is 800 lb. Thus, 24 × 800 = 19,200 lb., which is the safe load that the post will carry if hemlock is used. It will therefore be seen that, although cheaper, hemlock is not so good a material for posts as Georgia yellow pine. Ans.

3. Safe Loading of Long Posts.—In a long post, the strength depends not only on its cross-section, but also on its length. To find the safe strength of a long post, the area of the cross-section is multiplied by the safe strength per square inch taken from Table I, as before, and also by the proper constant taken from Table II. The constants in Table II, it will be noticed, depend both on the least thickness and on the length of the posts, both given in inches.

Example.—A 12″ × 14″ white-oak post is 18 feet long; what safe load will it carry?

Solution.—The length of the post, in inches, is 18 × 12 = 216, and the area of the post is 12 × 14 = 168 sq. in. From Table I, the safe strength per square inch for white oak is 900 pounds, and the nearest constant from Table II is .821. Therefore, the safe load that the post will carry is

$$168 \times 900 \times .821 = 124{,}135 \text{ lb. Ans.}$$

4. Design of Posts.—In designing a short post, it is simply necessary to divide the load to be carried by the safe strength per square inch as given in Table I, and the quotient will be the area of the post required. This method, however, cannot be followed with long posts. For long posts, it is first necessary to assume a section, and then see if the post is strong enough. If it is not, a larger section is assumed, and the problem worked out again. If the post is strong enough, a smaller one is assumed, to see whether a lighter post cannot be used just as well.

EXAMPLES FOR PRACTICE

1. What size white-pine post 4 feet long will support a load of 28,000 pounds? Ans. 5 in. × 8 in., or 4 in. × 10 in.

2. What is the safe strength of a 14″ × 14″ chestnut post 12 feet long? Ans. 175,616 lb.

STRENGTH OF BEAMS AND JOISTS

5. The strength of a beam or joist depends on its dimensions: the broader it is, the stronger; the longer it is, the weaker. The strength also varies directly as the square of the depth. The safe load per foot of length may be ascertained from the following formula:

$$w = \frac{k\,b\,d^2}{L^2}$$

in which w = safe load, in pounds per lineal foot, on beam;
b = breadth of beam, in inches;
d = depth of beam, in inches;
L = length of span, in inches;
k = a coefficient taken from Table I, to correspond with the variety of wood used.

Example.—What safe load per foot will a beam carry that is made of white pine 12 feet long, 6 inches wide, and 10 inches deep?

Solution.—Here, $L = 12 \times 12 = 144$; $b = 6$; $d = 10$; and $k = 10{,}700$. Therefore,

$$w = \frac{10{,}700 \times 6 \times 10 \times 10}{144 \times 144} = 310 \text{ lb. per ft.}$$

The total load that the beam will safely carry when uniformly distributed is the load per foot times the length of the beam, or

$$310 \times 12 = 3{,}720 \text{ lb.} \quad \text{Ans.}$$

6. Since the load a beam will carry depends directly on its breadth and on the square of its depth, it follows that the depth affects the strength of a beam more than the breadth;

that is, a 4″ × 12″ stick will be stronger when placed on edge than if placed flat. Thus, in designing a beam, it follows that the best plan is to make the beam as narrow and as deep as possible to save material. There is, however, a limit to the economy that may be gained in this direction, as lumber comes from the mill in certain sizes and cannot be readily obtained in odd dimensions. Also, a very thin beam is liable to split, warp, and twist sidewise, although it will not break square off as a thick beam. The designer, therefore, must use judgment in selecting the proportion of the depth to the breadth of the beam required.

EXAMPLE.—**Design a white-oak beam 16 feet long to carry a safe load of 400 pounds per foot.**

SOLUTION.—In this problem, the depth and the breadth of the beam are unknown, but if either is assumed, the other may be found. Therefore, let us assume a depth and find the breadth. If the beam then appears too wide for the assumed depth, a new and greater depth must be used and the problem worked over again.

Assume $d = 12$ in. From the problem, $L = 12 \times 16 = 192$; $w = 400$; and $k = 16{,}000$.

Substituting these values in the formula, Art. 5,

$$400 = \frac{16{,}000 \times b \times 12 \times 12}{192 \times 192}$$

Therefore, $$b = \frac{400 \times 192 \times 192}{16{,}000 \times 12 \times 12} = 6.4 \text{ in.}$$

The beam should therefore be 12 in. deep and 6.4 in. wide. As timber does not come from the mill 6.4 in. wide, an 8″ × 12″ stick may be used. Ans.

7. When the load on a beam is concentrated at the center, the formula to be used is as follows:

$$w^1 = \frac{k\,b\,d^2}{24\,L}$$

in which w^1 = safe load concentrated at center of beam, in pounds;

b = breadth of beam, in inches;

d = depth of beam, in inches;

L = length of beam, in inches;

k = proper constant from Table I.

EXAMPLE 1.—What safe concentrated load at the center will a spruce beam carry if it has a span of 24 feet and is 14 inches deep and 12 inches broad?

SOLUTION.—Here $b = 12$; $d = 14$; $L = 24 \times 12 = 288$; and $k = 10{,}700$. Therefore,

$$w^1 = \frac{10{,}700 \times 12 \times 14 \times 14}{24 \times 288} = 3{,}641 \text{ lb. Ans.}$$

EXAMPLE 2.—Design a red-pine beam on a 10-foot span to carry a safe load of 10,000 pounds concentrated at the center.

SOLUTION.—Assume $d = 14$. Since $k = 13{,}300$, $w^1 = 10{,}000$, and $L = 10 \times 12 = 120$;

$$10{,}000 = \frac{13{,}300 \times b \times 14 \times 14}{24 \times 120}$$

Therefore, $$b = \frac{10{,}000 \times 24 \times 120}{13{,}300 \times 14 \times 14} = 11 \text{ in.}$$

As the next commercial size is 12 in., the beam to be used is 12 in. × 14 in. Ans.

EXAMPLES FOR PRACTICE

1. What safe distributed load per foot will a California redwood beam carry, the beam having a span of 16 feet 8 inches, and being 10 inches deep and 8 inches broad? Ans. 240 lb. per ft.

2. In the example just given, what safe load concentrated at the center will the beam carry? Ans. 2,000 lb.

3. Design a spruce beam on an 11-foot span to carry a safe load of 1,500 pounds per foot. Assume the beam to be 16 inches deep. Ans. 10 in. × 16 in.

4. Design a spruce beam on an 11-foot span to carry a safe load of 10,000 pounds concentrated at the center, the depth of the beam being 16 inches. Ans. 12 in. × 16 in.

GIRDERS

CAMBERED GIRDERS

8. **Kingposts and Queenposts.**—When wooden girders of great span are heavily loaded, it becomes necessary to strengthen them with steel cambered rods, as shown in Figs. 1 and 2, which represent girders having one and two intermediate supports, respectively. When one intermediate support is used, as in Fig. 1, the support is called a **kingpost;** and when two intermediate supports are used, as in Fig. 2, the supports are called **queenposts.** The design of the four principal arrangements of loads, etc. will now be discussed.

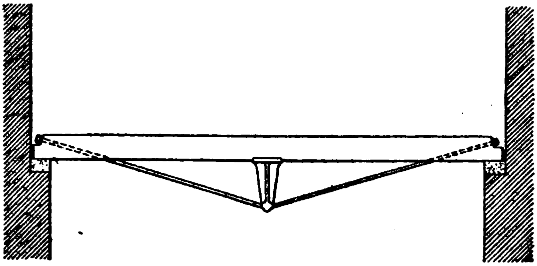


FIG. 1

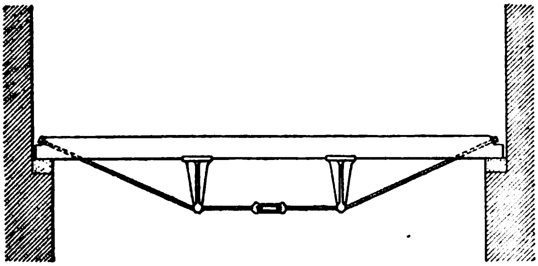


FIG. 2

9. Case I.—The first case is a kingpost girder with a concentrated load W over the kingpost, as shown in Fig. 3. With this loading, the member DC is in compression, and is designed like a post; AC and CB are in tension; while AB is in compression, and is designed like two posts placed end to end, as AD and DB. In construction, AB is usually made of wood; AC and CB, of steel in the shape of a round rod; while DC is sometimes made of wood and sometimes of cast iron. The safe allowable tension in the steel is 16,000 pounds per square inch, and the safe allowable compression in the cast iron is 10,000 pounds per square inch.

The stress in DC is equal to the concentrated load W. To find the stress in AC or BC, divide the length of the line AC by the length of the line DC, and then multiply this result by one-half of the load W. To find the stress in the beam AB, divide the length of the line AD by the length of the line DC, and multiply this result by one-half of the load W. In designing a cambered girder, it is sometimes found that the girder or the kingpost is a very small stick indeed. Such small sizes, however, are seldom used, and in a case like this the designer generally uses his own judgment in selecting a larger size, which, besides being strong enough to withstand the calculated load, will also withstand any accidental load that may be applied.

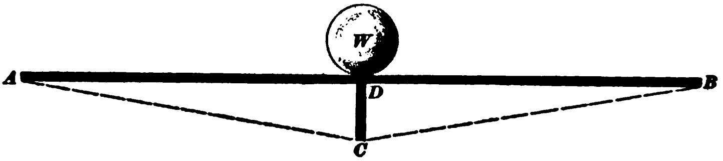


FIG. 3

EXAMPLE.—Design a beam like the one shown in Fig. 3, when $W = 25{,}000$ pounds, $AB = 30$ feet, $AD = 15$ feet, and $DC = 2$ feet.

SOLUTION.—The stress in DC being equal to W is 25,000 lb. The allowable unit stress, if DC is made of cast iron, is 10,000 lb. per sq. in., and if of Georgia yellow pine, 1,000 lb. per sq. in. The area of DC, if made of cast iron, is therefore $25{,}000 \div 10{,}000 = 2.5$ sq. in., while, if made of yellow pine, its area is $25{,}000 \div 1{,}000 = 25$ sq. in.

By geometry, the length of AC and BC is found to be equal to $\sqrt{15^2 + 2^2} = 15.1327$. Therefore, the stress in AC or BC is

$$\frac{15.1327 \times 25{,}000}{2 \times 2} = 94{,}579 \text{ lb.}$$

and the area of AC or BC is $94{,}579 \div 16{,}000 = 5.911$ sq. in. By referring to Table III, it will be found that the smallest commercial size of round iron having the required area at the root of the thread cut for a turnbuckle or end nuts is a 3¼-in. rod. The stress in AD or DB is

TABLE III

STANDARD DIAMETER OF THREADED RODS AND BOLTS

Diameter of Rod or Bolt Inches	Diameter at Root of Thread Inches	Area of Rod or Bolt at Root of Thread Inches	Diameter of Rod or Bolt Inches	Diameter at Root of Thread Inches	Area of Rod or Bolt at Root of Thread Inches
¼	.185	.026	1½	1.284	1.294
5/16	.240	.045	1⅝	1.389	1.515
⅜	.294	.067	1¾	1.491	1.746
7/16	.344	.092	1⅞	1.616	2.051
½	.400	.125	2	1.712	2.301
9/16	.454	.161	2¼	1.962	3.023
⅝	.507	.201	2½	2.176	3.718
¾	.620	.301	2¾	2.426	4.622
⅞	.731	.419	3	2.629	5.428
1	.837	.550	3¼	2.879	6.509
1⅛	.940	.693	3½	3.100	7.547
1¼	1.065	.890	3¾	3.318	8.641
1⅜	1.160	1.056	4	3.567	9.993

$$\frac{15 \times 25{,}000}{2 \times 2} = 93{,}750 \text{ lb.}$$

Assuming AB as being made of Georgia yellow pine, the allowable stress per square inch will therefore be 1,000 lb. It can thus be seen that this post will be a long post; that is, its length, 15 ft., will be longer than ten times its least thickness of cross-section. Therefore, a certain sized post must be assumed to see if it will be strong enough. Thus, assume a section of 10 in. × 12 in.; then the safe working load is 1,000 × 120 × .82 = 98,400 lb. Since this is larger than 93,750 lb., the stress produced, the beam is strong enough. Ans.

10. Case II.—The second case to be considered is a girder braced with queenposts, and having a concentrated load on the girder above each post, as shown in Fig. 4. Here, AB, BC, and CD are in compression, and are designed as before. The members BH and CE are in compression, and AH, HE, and ED are in tension. Let each load equal W, then the stress in both BH and CE equals W. To obtain the stress in AH or DE, divide the length of AH by the length BH, and multiply this result by the amount of the load W. To find the stress in AD or HE, divide the length of the line AB by the length of the line BH, and multiply this result by the amount of the load W.

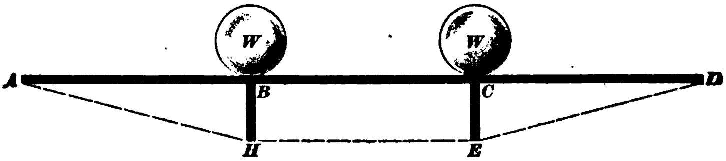


FIG. 4

EXAMPLE.—Design a trussed beam that is 48 feet long and is divided into three equal panels by queenposts to support concentrated loads of 20,000 pounds over each queenpost. The length of the queenpost from the center of the beam is 3 feet.

SOLUTION.— $BH = 3$ ft., and $AB = 48 \div 3 = 16$. By geometry, $AH = \sqrt{16^2 + 3^2} = 16.2788$ ft. The stress BH or CE is 20,000 lb. If the post is of cast iron, it need only be $20{,}000 \div 10{,}000 = 2$ sq. in. in section; but as a matter of fact it would probably be made larger in section for convenience in design. If made of Georgia yellow pine, the post will be $20{,}000 \div 1{,}000 = 20$ sq. in. in cross-section. The stress in AH or ED is

$$\frac{16.2788}{3} \times 20{,}000 = 108{,}526 \text{ lb.}$$

Dividing this by 16,000 gives the area of the rod required: thus, $108{,}526 \div 16{,}000 = 6.783$. The smallest commercial size of round iron, from Table III, that has the required area at the root of the thread cut for nuts or a turnbuckle is a $3\frac{1}{2}$-in. rod. The stress in AB is equal to $\frac{16}{3} \times 20{,}000 = 106{,}667$ lb. Assume that the beam is made of Georgia yellow pine; then the allowable stress per square inch will be 1,000 pounds. It can thus be seen that this post will be a long post. Therefore, assume a post of 10″ × 14″ timber; the strength is

$$10 \times 14 \times 1{,}000 \times .81 = 113{,}400 \text{ lb.}$$

which is greater than 106,667 lb., or the actual stress produced. The stress in HE will be the same as that in AB, namely, 106,667 lb., but will be in tension instead of compression. As a matter of fact, however, AH, HE, and ED are all one continuous rod, so the diameter of HE is also $3\frac{1}{4}$ in. Ans.

11. Case III.—The third case is a girder braced with a kingpost and supporting a continuous load, as shown in Fig. 5. The tie-rods AC and CB are in tension, the kingpost DC is in compression, and the beam AB is also in compression and subjected to bending in addition. The design of such a trussed beam is divided into two parts: First, one-half of the total load is considered concentrated over the kingpost, and the system is designed as in Case I, except that AD and DB are always considered as short posts, no matter what is the ratio of the length to the least thickness of the cross-section. Second, the beam proper AB is considered as two beams of lengths AD and DB, and enough material is added to the design already accomplished to take care of the bending moment due to the superimposed load. This method of design is more conservative than other methods sometimes employed, as here the beam AB may be actually made in two parts and jointed at D and the design will still be safe.

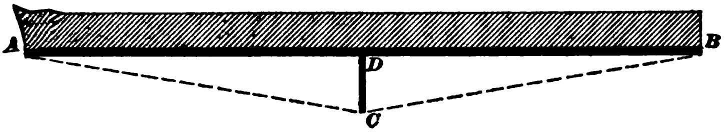


FIG. 5

EXAMPLE.—Design a beam on a 30-foot span with a 4-foot kingpost, to carry a uniformly distributed load of 1,000 pounds per running foot.

SOLUTION.—By geometry, $AC = \sqrt{15^2 + 4^2} = 15.5242$ ft. The total load on the beam is $1,000 \times 30 = 30,000$ lb. One-half of this is the equivalent of a concentrated load, and is $30,000 \div 2 = 15,000$ lb. This is the stress in the kingpost DC, and if it is made of cast iron, the area of its section will be $15,000 \div 10,000 = 1\frac{1}{2}$ sq. in., although in actual design, it will be found more convenient to make it larger. If made of Georgia yellow pine, the area of the section, from Table I, will be 15,000 ÷ 1,000 = 15 sq. in., although it would probably be made larger to avoid considering it as a long post. The stress in AC and CB is one-half the concentrated load times AC divided by DC, or

$$\frac{15{,}000 \times 15.5242}{2 \times 4} = 29{,}108 \text{ lb.}$$

Dividing this by 16,000, the safe allowable tensile stress in the steel, it is 29,108 ÷ 16,000 = 1.819 sq. in. The rod with the smallest area at the root of the thread cut for a turnbuckle is $1\frac{7}{8}$ in. in diameter. The compressive stress in AD and DB, respectively, is

$$\frac{15{,}000 \times 15}{2 \times 4} = 28{,}125 \text{ lb.}$$

If the beam is made of Georgia yellow pine, the allowable compressive stress is 1,000 lb. per sq. in. 28,125 ÷ 1,000 = 28.125 sq. in. Assume the depth to be 14 in., then the width to resist compression will be 28.125 ÷ 14 = 2+ in.

It is now necessary to design the beam for bending by using the formula of Art. **5.** Referring to Table I for Georgia yellow pine, $k = 18{,}700$. Also from the conditions of the problem, $L = 12 \times 15 = 180$; $w = 1{,}000$; and d is also known to be 14 in., as it is necessary to make the depth of the part of the beam to resist bending the same as that part designed to resist compression. Substituting these values in the formula,

$$1{,}000 = \frac{18{,}700 \times b \times 14 \times 14}{180 \times 180}$$

or,

$$b = \frac{1{,}000 \times 180 \times 180}{18{,}700 \times 14 \times 14} = 8.84, \text{ say } 8\tfrac{7}{8}, \text{ in.}$$

This thickness should be added to the thickness already found to resist direct compression, thus, $8\frac{7}{8} + 2 = 10\frac{7}{8}$. The beam must therefore be 14 in. deep and $10\frac{7}{8}$ in. broad, but as $10\frac{7}{8}$ is not a commercial size, the size stick actually employed will be 12 in. × 14 in. Ans.

12. Case IV.—The fourth case is a girder braced with queenposts and supporting a continuous load, as shown in Fig. 6. The tie-rod $AHED$ is in tension, the queenposts BH and CE are in compression, and the beam AD is in compression and also subjected to bending. As in Case III, the design is divided into two parts: First, one-third of the

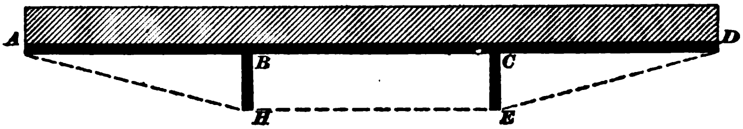


FIG. 6

total load is considered concentrated over each queenpost, and the system is designed as in Case II, except that AB, BC, and CD are always considered as short posts, no matter what is the ratio of the length to the least thickness of the cross-section. Second, the beam proper AD is considered as three beams AB, BC, and CD, and enough material is added to the design already completed to take care of the bending moment due to the load per foot.

Example.—Design a beam on a 36-foot span with 3-foot queenposts, to carry a uniformly distributed load of 1,500 pounds per running foot.

Solution.—By geometry, $AH = \sqrt{12^2 + 3^2} = 12.3693$ ft. The total load on the beam is $1,500 \times 36 = 54,000$ lb.; one-third of this is equivalent to each concentrated load, and is 18,000 lb., which is the stress in the queenposts BH and CE. If they are made of cast iron, the section of each will be $18,000 \div 10,000 = 1.8$ sq. in., although in actual design it will be found convenient to make them larger. If made of white oak, the area of each section, from Table I, will be $18,000 \div 900 = 20$ sq. in. The stress in AH and ED is

$$18,000 \times \frac{12.3693}{3} = 74,216 \text{ lb.}$$

Dividing this by 16,000, the allowable stress in the steel, it is $74,216 \div 16,000 = 4.64$ sq. in. Since HE is part of the same rod, it will be made the same size as AH and ED, even if the stress in it is not quite so large. The rod with the smallest area at the bottom of the thread cut for a turnbuckle is 3 in. in diameter. The compressive stress in AB, BC, and CD is $18,000 \times \frac{12}{3} = 72,000$ lb. If the beam is made of white oak, the allowable compressive stress is 900 lb. per sq. in., and $72,000 \div 900 = 80$ sq. in. Assume the depth of the beam to be 16 in., then the width to resist compression will be $80 \div 16 = 5$ in.

To design the beam for bending, the formula given in Art. 5 is used. From Table I, for white oak, $k = 16,000$; $L = 12 \times 12 = 144$; $w = 1,500$; and d is the same as before, namely, 16 in. Substituting these values in the formula,

$$1,500 = \frac{16,000 \times b \times 16 \times 16}{144 \times 144}$$

or,

$$b = \frac{1,500 \times 144 \times 144}{16,000 \times 16 \times 16} = 7.59, \text{ say } 7\tfrac{5}{8}, \text{ in.}$$

The total width of the beam required, therefore, is $5 + 7\frac{5}{8} = 12\frac{5}{8}$ in. Thus, the beam should be $12\frac{5}{8}$ in. × 16 in., but as sticks of this size cannot be obtained, it would probably be built of two 8 in. × 16 in. packed with, say, 3-in. packing.

EXAMPLES FOR PRACTICE

1. A girder trussed with a kingpost supports a concentrated load of 10,000 pounds placed at the center. The span is 28 feet and the kingpost is 3 feet. Both the girder and the kingpost are made of hemlock. What is the smallest dimension of the various members, if it is decided to make the girder 8 inches deep?

Ans.—Area of kingpost, $12\frac{1}{2}$ sq. in.; area of rod, 1.49 sq. in.; girder, 6 in. × 8 in.

2. A girder trussed with queenposts, supports two concentrated loads of 8,000 pounds each, one placed over each queenpost. The span is 33 feet and the queenposts are each 2 feet 6 inches. The girder is made of California spruce and the queenposts are of hemlock, and it is decided to make the girder 8 inches deep. What are the minimum dimensions of the various pieces?

Ans.—Area of queenposts, 10 sq. in. each; area of truss rod, 2.256 sq. in.; dimensions of girder, 8 in. × 8 in.

3. A kingpost girder is made of Georgia yellow pine. The post itself is made of cast iron, and is 4 feet long from the center of the girder. The span is 40 feet, and the girder carries 1,500 pounds per foot. The largest stick that can be obtained from the mill is 18 inches. Design the girder.

Ans.—Area of kingpost, 3 sq. in.; area of rod, 4.78 sq. in; beam is 18.427 in. wide, and in actual practice would consist of two sticks 10 in. × 18 in.

4. A queenpost girder is made of white oak. The queenposts are also of oak and are 3 feet long, each from the center of the beam. The span is 36 feet, and the girder carries 1,000 pounds per foot. It is decided to make the stick 16 inches deep. Design the beam.

Ans.—Area of queenpost, 13.3 sq. in.; area of rods, 3.09 sq. in.; beam is 8.396 in. × 16 in., say, 10 in. × 16 in.

FLITCH-PLATE GIRDERS

13. A **flitch-plate girder** is composed of a steel plate having a wooden beam bolted on each side. The girder should have two lines of bolts, as shown in Fig. 7, the distance between centers on each line being twice the depth of the girder, while at each end there should be two bolts in the same vertical line. The strength of such a girder is equal to the strength of the wood plus the strength of the steel plate. Since, however, the two materials are bolted together and bend together, for reasons not here discussed, the wood cannot exert its full strength, and instead of using the constant k from Table I for the formulas of Arts. **5** and **6**, the constant r from the same table should be employed. The load that steel will carry will be found by the same formulas that are used for the wooden part, the only difference being the constant r, which for steel is 256,000. In designing flitch-plate girders, the size of the steel plate is usually assumed first, and the correct amount of wood is added afterwards.

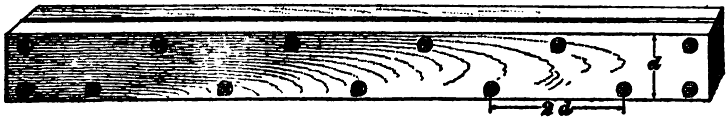


FIG. 7

EXAMPLE 1.—Design a flitch-plate girder that, on a span of 17 feet 6 inches, will carry a safe load of 1,100 pounds per foot. Assume the flitch plate to be $\frac{3}{4}$ in. × 12 in.

SOLUTION.—The load per foot that the steel will carry is found by the formula $w = \frac{r b d^2}{L^2}$, where $r = 256{,}000$; $b = \frac{3}{4}$; $d = 12$; and $L = 17.5 \times 12 = 210$. Substituting these values in the equation,

$$w = \frac{256{,}000 \times .75 \times 12 \times 12}{210 \times 210} = 627 \text{ lb.}$$

This is the amount of load per foot that the steel will carry. The amount left is, therefore, $1{,}100 - 627 = 473$ lb. per ft., and is the weight that the wood must be designed to carry. The wood must have the same depth as the plate, namely 12 in. Assume that Georgia yellow pine is to be used; then from Table I, r equals 15,007. Substituting the values known, the equation $w = \frac{r b d^2}{L^2}$ becomes

$$473 = \frac{15{,}007 \times b \times 12 \times 12}{210 \times 210}$$

Therefore, $$b = \frac{473 \times 210 \times 210}{15{,}007 \times 12 \times 12} = 9.65, \text{ say } 10, \text{ in.}$$

The girder should therefore have 5 in. of wood on each side of the steel plate. Ans.

EXAMPLE 2.—A flitch-plate girder is on a 22-foot span and is made of 1″ × 14″ steel plate and two 6″ × 14″ white-oak sticks; what safe load concentrated at the center will it carry?

SOLUTION.—The formula for concentrated loads is $w^1 = \frac{r b d^2}{24 L}$. For the wood, $r = 9{,}710$; $b = 2 \times 6 = 12$; $d = 14$; and $L = 22 \times 12 = 264$. Therefore,

$$w^1 = \frac{9{,}710 \times 12 \times 14 \times 14}{24 \times 264} = 3{,}604 \text{ lb.}$$

which is the load that the wooden part of the beam will carry. For the steel part $r = 256{,}000$; $b = 1$; $d = 14$; and $L = 264$. Therefore,

$$w^1 = \frac{256{,}000 \times 1 \times 14 \times 14}{24 \times 264} = 7{,}919 \text{ lb.}$$

Thus, the total concentrated load that the flitch plate will carry is

$3{,}604 + 7{,}919 = 11{,}523$ lb. Ans.

EXAMPLES FOR PRACTICE

1. Design a flitch-plate girder on a 10-foot span to carry a load of 9,650 pounds per foot, the beam to be of yellow fir, and the flitch plate of 2″ × 14″ steel.

Ans. Plate to be flitched with an 8″ × 14″ stick on each side

2. What uniform load per foot will a flitch-plate girder carry on a 22-foot span, the girder being composed of a 1″ × 12″ steel plate and two 6″ × 12″ Georgia yellow-pine sticks? Ans. 901 lb. per ft.

3. Design a flitch-plate girder on a span of 16 feet, to carry a safe load of 12,000 pounds concentrated at the center. The plate is to be $1\frac{1}{4}$ in. × 12 in., and the wooden sticks are to be made of chestnut.

Ans. Plate to be flitched with a 4″ × 12″ stick on each side

4. What safe load concentrated at the center will a flitch-plate girder carry on a 19-foot span, the girder being composed of a $1\frac{1}{2}$ × 10″ steel plate and two 5″ × 10″ Georgia yellow-pine sticks?

Ans. 9,760 lb.

TRUSSED ROOFS

SIMPLE TRUSSES

14. **Flat Roofs.**—The simplest form of roof for a building is a **flat roof.** There are two serious disadvantages to a flat roof, however: one is that it does not shed water, and the other is that beams for large areas, strong enough to support it, are difficult to obtain. To overcome both of these drawbacks, roofs are often made more or less peaked. In such a case, the framework holding up the roof covering is called a **roof truss.**

The analysis of the stresses in a roof truss will be explained in a later Section, and here will only be given examples of some simple trusses and the sizes of scantling usually employed in good practice in their construction.

15. **Couple Roof.**—What is probably the simplest form of roof truss is shown in Fig. 8, and is known as the **couple roof.** It consists principally of two rafters *a*, *a*, the feet of which are nailed and frequently notched to the wall plates *b*, *b*. The heads of the rafters butt against a ridge board *c* to which they are secured by nails. The inclination of the rafters varies, but for slate roofs it is usually about such that the rise is equal to one-quarter of the span. Good practice dictates that the sizes of scantling given in Table IV will usually be found to give excellent results.

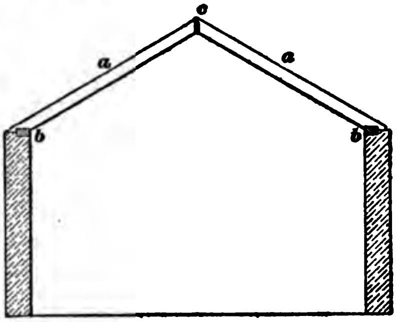


FIG. 8

TABLE IV
SCANTLING FOR COUPLE ROOFS

Span From Center to Center of Wall Plates Feet	Rafters *a* Inches	Ridge Board *c* Inches	Ceiling Joists, if Used Inches
8	2 × 4	1½ × 7	2 × 4
10	2 × 4	1½ × 7	2 × 5
12	3 × 4	1½ × 7	2 × 6
14	2 × 5	1½ × 8	2 × 7
16	2 × 6	1½ × 8	2 × 8
18	3 × 6	1½ × 8	2 × 9

16. Couple-Close Roofs.—The truss shown in Fig. 8 has a tendency to push out the side walls of the building, and should not be used on a span greater than 12 feet without some precaution being taken to receive the thrust of the rafters. One method of avoiding this thrust is to use a ceiling joist, as shown at *a*, Fig. 9, the sizes of which are given in Table IV. This ceiling joist is often called a *tie-beam*, and a truss as shown in Fig. 9 is called a **couple-close roof.**

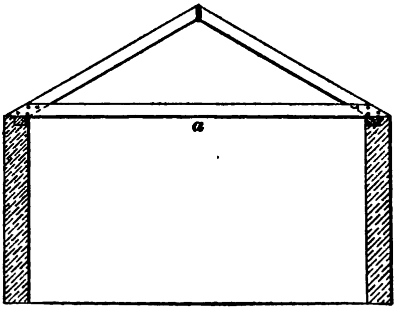


FIG. 9

17. Collar-Beam Roofs.—Where it is desired to have more headroom in buildings, the truss is often built as shown in Fig. 10. The tie *a*

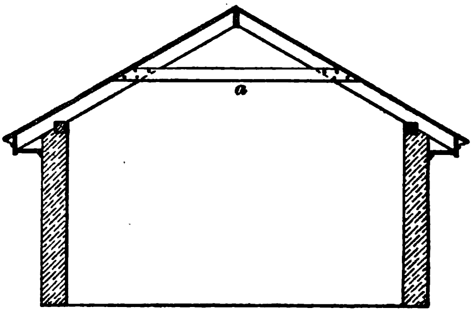


FIG. 10

is called a *collar*, and the roof is known as a **collar-beam roof.** Usually, the collar is placed half way up the rafters, but this construction is not considered very strong. The dimensions of the stick vary according to whether the wall can take any thrust from the rafters or whether all the thrust must be carried by the collar, and also whether any ceiling is used. The dimensions of scantling to use when the pitch of the roof makes an angle of 30° with the horizontal is given in Table V.

TABLE V

SCANTLING FOR COLLAR-BEAM ROOFS

Span	Rafters				Collars	
	Thrust Taken by Walls		Thrust Taken by Collars			
Feet	No Ceiling Inches	Ceiled to Collars Inches	No Ceiling Inches	Ceiled to Collars Inches	No Ceiling Inches	Ceiled to Collars Inches
8	2 × 3	2 × 4	3 × 4	3 × 4	2 × 3	2 × 4
10	2 × 3	2 × 4	3 × 5	3 × 5	2 × 3	2 × 4
12	2 × 4	2 × 4	3 × 5	3 × 6	2 × 3	2 × 5
14	2 × 4	3 × 4	3 × 6	3 × 6	2 × 4	2 × 6
16	3 × 4	3 × 4	3 × 6	3 × 8	2 × 4	2 × 6
18	3 × 4	3 × 4	3 × 8	3 × 10	3 × 4	2 × 6

KINGPOST TRUSS

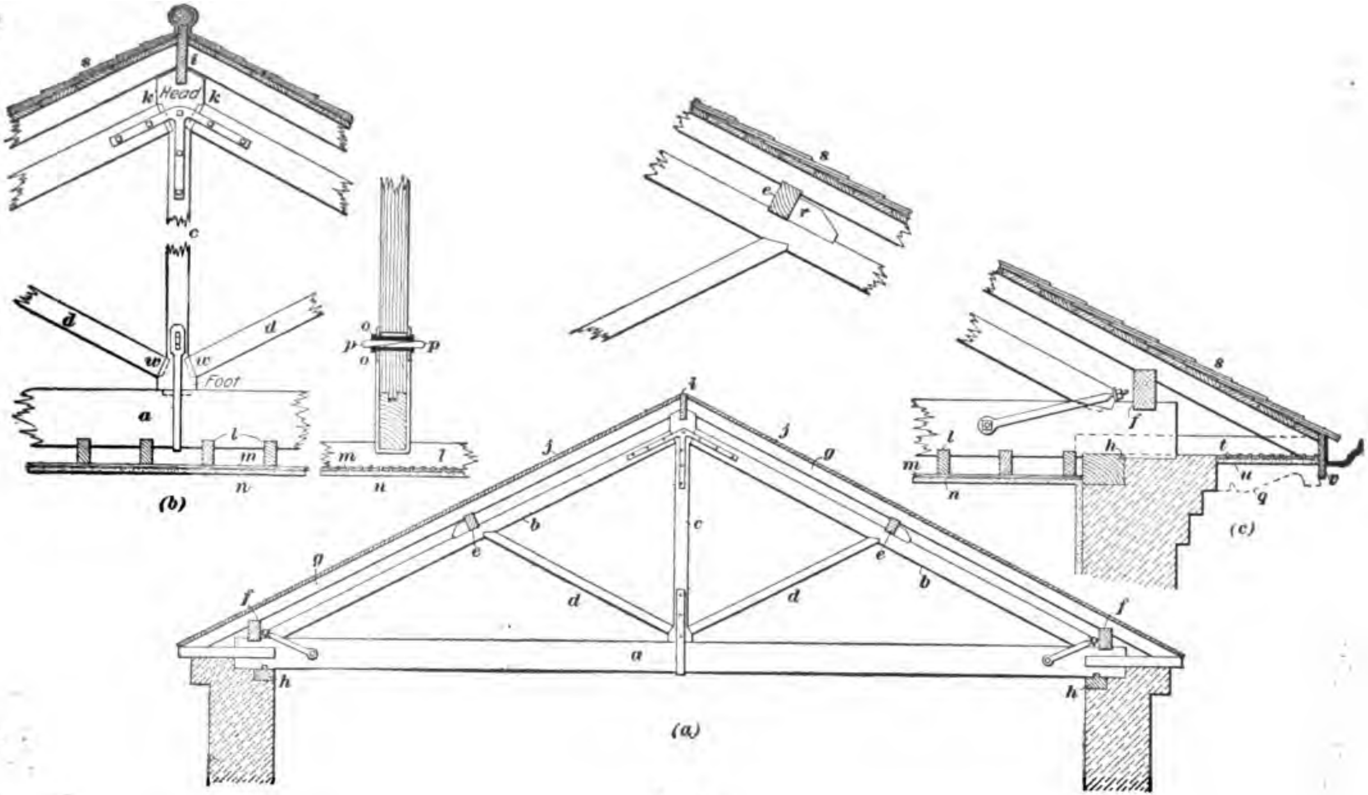
18. One of the simplest forms of trusses, called a **kingpost truss,** is shown in Fig. 11 (*a*), which illustrates a truss built entirely of wood. Here, *a* is the tie-beam, or chord; *b, b*, the principal rafters; *c*, the kingpost; and *d, d*, the braces, or struts. The trusses are placed on, say, 10-foot centers, and from truss to truss run the purlins *e, e* and the pole plates *f, f*. On these purlins are placed the common rafters *g, g*, usually on 12-inch centers, while the ends of the chord generally rest on the wall plates *h, h*. At *i* is shown the ridge board, and at *j, j*, the roof boards. The size of scantling for such a truss varies with different builders, and also depends on the conditions under which the truss is built and on its proportion. For a rise of one-fourth of the span, which is about right for slate, the dimensions given in Table VI will be found amply safe. The chord may be made somewhat lighter than given if no ceiling is attached to it.

19. A detail of the kingpost is shown in Fig. 11 (*b*). The two struts *d, d* are mortised into the foot of the kingpost at *w, w*, as shown, and the principal rafters are also mortised into the kingpost at *k, k*, at the head. The head of the post is extended, and into it is gained the ridge board *i*. By doing this, the necessity of having a purlin at the peak to hold up the common rafter *g* is obviated. The slates are shown at *s*, and at the bottom of the figure are shown the ceiling joists *l*, which are notched to fit the chord *a*. Under these joists are fastened the lath and plaster *m* and *n*, as shown. The head of the kingpost is fastened to the principal rafters by an iron strap on each side, these straps being secured together by bolts that go directly through the wood. The foot of the kingpost is made fast to the chord by an iron band, as shown in the illustration. The section also shows the two gibs *o, o* and two cotters *p, p* used to draw the band tight.

TABLE VI

SCANTLING FOR KINGPOST TRUSS

Span Feet	Chord *a* Inches	Kingpost *c* Inches	Principal Rafters *b* Inches	Braces or Struts *d* Inches	Purlins *e* Inches	Common Rafters *g* Inches
20	4 × 10	3 × 4	4 × 4	2 × 4	6 × 8	2 × 4
22	5 × 10	3 × 5	3 × 5	2 × 4	6 × 8	2 × 4
24	5 × 12	4 × 5	4 × 5	3 × 4	6 × 8	2 × 4
26	5 × 12	4 × 5	5 × 5	3 × 4	6 × 8	2 × 5
28	6 × 12	4 × 6	4 × 6	3 × 5	6 × 10	2 × 5
30	6 × 12	5 × 6	4 × 6	3 × 5	6 × 10	2 × 5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i
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Foot
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FIG. 11

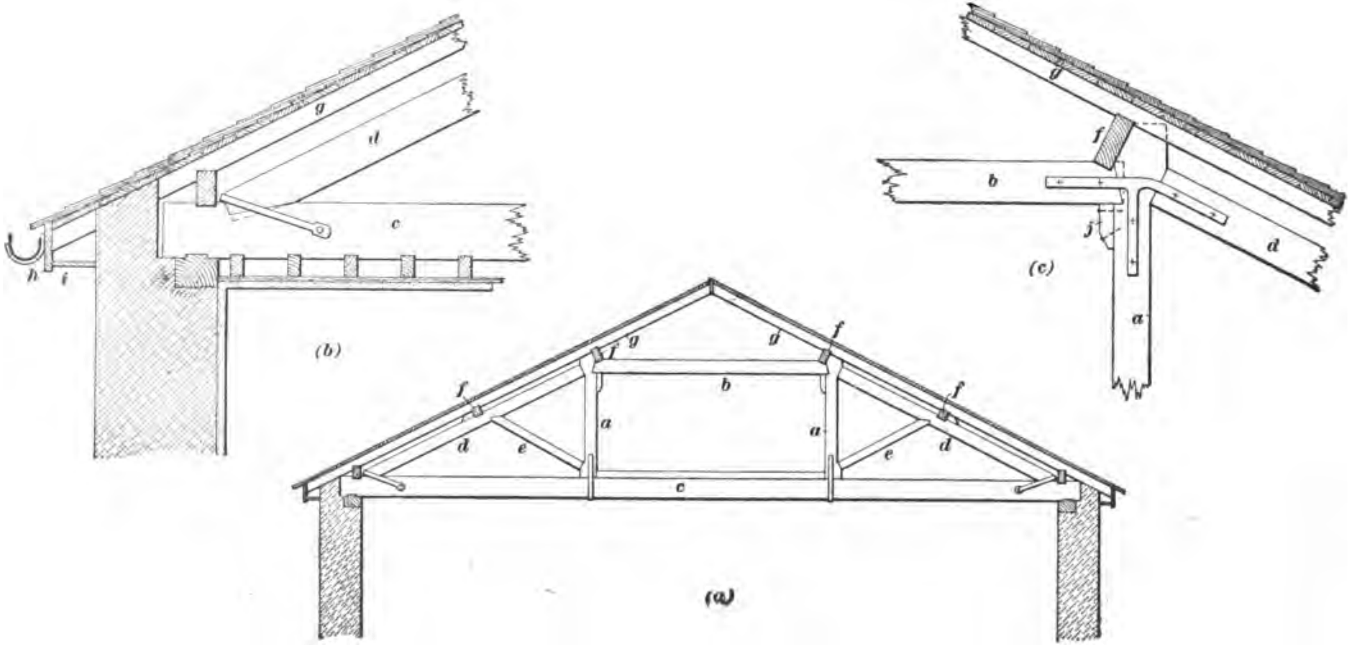

FIG. 12

TABLE VII

SCANTLING FOR QUEENPOST TRUSS

Span Feet	Chord *c* Inches	Queenpost *a* Inches	Principal Rafters *d* Inches	Straining Beams *b* Inches	Struts or Braces *e* Inches	Purlins *f* Inches	Common Rafters *g* Inches
32	4 × 12	4 × 6	4 × 6	4 × 8	3 × 4	6 × 8	2 × 4
34	4 × 12	4 × 6	4 × 6	4 × 8	3 × 4	6 × 8	2 × 4
36	4 × 12	4 × 6	4 × 8	4 × 8	3 × 4	6 × 8	2 × 4
38	6 × 12	4 × 6	6 × 8	6 × 8	3 × 4	6 × 8	2 × 4
40	6 × 12	6 × 6	6 × 8	6 × 8	3 × 4	6 × 10	2 × 5
42	6 × 12	6 × 6	6 × 8	6 × 10	3 × 6	6 × 10	2 × 5
44	8 × 12	6 × 8	6 × 8	8 × 8	3 × 6	6 × 10	2 × 5
46	8 × 12	6 × 8	6 × 8	8 × 8	3 × 6	6 × 10	2 × 6

20. In Fig. 11 (*c*) is shown the method of constructing the truss on the sides. At *s* are shown the slates, while the purlin *e* is held in place by the cleat *r*. Properly, the pole plate *f* should be located directly over the wall plate; but as in this particular instance such a location would be unfavorable and not on the chord, the pole plate has been set a little farther out. The plancher piece, or lookout, *t* holds the soffit, or plancher *u*, which is here shown made of lath and plaster, although it is often made of wood, and the fascia *v* is nailed to the end of the common rafter. In some cases the soffit is supported by consoles, as shown dotted at *q*, instead of the plancher piece *t*. The ceiling joists and lathing are shown at *l* and *m*, and the plaster at *n*.

QUEENPOST TRUSS

21. A **queenpost truss** shown in Fig. 12 (*a*) is a good truss if the loads are evenly balanced. The two queenposts are shown at *a*, *a*, and the straining beam at *b*. As a rule, the queenpost truss is used for larger spans than the kingpost truss. The size of scantling for a rise of one-fourth span is given in Table VII. The dimensions in Table VII have been calculated for trusses 10 feet apart, but the trusses may be placed at a greater distance, and if no ceiling joists are used, the chord may be made smaller.

22. In Fig. 12 (*b*) is shown a detail of the construction of the truss over the wall, which is practically the same as is followed in constructing the kingpost truss. Here, however, for variety, the gutter is shown closer to the wall, reducing the overhang of the roof. By this construction the plancher piece may be omitted, and the fascia *h*, which is nailed directly to the common rafter, made to support the soffit *i*. In Fig. 12 (*c*) is shown the detail of the head of the queenpost. Against this head rests the purlin *f*, while the cleat *j* helps support the straining beam *b*. A wrought-iron strap is used on both sides of the timber, and through bolts hold the joint firmly in place.

JOINERY

(PART 1)

PROVINCE OF JOINERY

1. Joinery, as distinguished from *carpentry*, relates to that branch of the woodworking trades which deals with those interior and exterior fittings of a house that are put in place after the rough framework and flooring are finished, such as the floors, skirtings, casings, wainscotings, doors, windows, paneled partitions, stairways, etc.

In joinery, close-fitting joints, accurate workmanship, and smooth-finished surfaces are the chief points in view, as contrasted with the work of the carpenter, whose main object is to provide a frame, or skeleton, that will be strong enough to resist any stress to which the building may be subjected and that will be arranged to comply with the requirements of the finished joinery.

Hence, while the carpenter deals principally with heavy timbers in the rough, the joiner uses smaller pieces of finer and more carefully seasoned woods, and joins and fits them with the utmost accuracy. The joiner, therefore, must work with much more care and to a higher degree of finish than the carpenter. All the surfaces that the joiner leaves exposed must be smooth and clean, ready for the painter, varnisher, or polisher.

The joiner's time is spent between the duties of the workshop and the building. In the workshop, he prepares the framed and paneled work, door frames and casings, window

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frames and sash, all classes of molded work, and the various parts required for stairways, general trim, and interior fittings. In the building, he attaches the finished woodwork to the framed base, consisting of false jambs, furring strips, and grounds, all of which he should verify as to correct leveling, plumbing, and alinement before he applies the materials. True, these should have been placed correctly by the carpenter, but a careful joiner will always make an examination of existing conditions, so that he may better meet them intelligently.

JOINTS

2. **Classes of Joints in Joinery.**—To insure durable and flush connections between the parts joined together, due consideration should be given to the form and character of the joints, so that the strains to which they are subjected may be either resisted or compensated. The strains may be caused either by the behavior of the material itself or by extraneous force in the working portions, as doors, shutters, and window sashes.

In *Carpentry*, a number of joints commonly used in house building are described in detail; and though many of these joints are identically the same in principle as those used in joinery, there is a vast difference in the degree of accuracy required in the workmanship. In joinery, the joints may be divided into two classes; namely, *loose joints* and *glued joints*. The former consists of two or more pieces held in place, primarily, by the shape of the parts of union, although glued when put together for interior work, such as the dovetail joint, Figs. 8, 9, 10, and 11; in the latter, the pieces are secured by means of glue, as in the miter joint, Fig. 2, the half corner, Fig. 3, etc.

3. **Loose joints** are seldom used in joinery, except in heavy machine frames and in pieces of cabinetwork that are made in sections for convenience in handling, or in the exterior finish of a building where exposure to the weather would render the glued joint unreliable; and, in any case,

the loose joint is usually rendered additionally secure by means of screws, nails, or wooden pins.

4. **Glued joints** require some mechanical contrivance to hold the parts in position while the glue is setting, which usually requires from 12 to 48 hours, according to the quality of the glue, the condition of the atmosphere, and the temperature of the room.

5. Considerable experience is required in order to use glue successfully. The wood must be well seasoned and thoroughly dry, and the joint must be well fitted. In gluing hardwoods, the surfaces to be glued should be roughened with a toothed comb, to make the glue hold better, the room must be at a proper temperature, and the material must be heated, so that the glue will flow quite freely. The glue should be spread evenly on the parts, which are then placed together as soon as possible and held in place by means of hand screws, bench clamps, or wedged frames. All superfluous glue is then wiped off, and the work is allowed to stand until the joint is thoroughly dry.

The most frequent causes of bad gluing are the use of inferior glue and the unequal spreading of it. A good practical way to test any brand of glue is to glue together a piece of pine and a piece of ash, clamp them up with a hand screw, and when they are dry insert a chisel in the joint and try to pry them apart. If the joint separates where it is glued, the adhesion is inferior, and the glue should not be used for good work. The wood should split, or give way, rather than the material that secures the joint.

6. **Butt Joints.**—The simplest joint made use of in joinery is the **butt joint,** shown in Fig. 1. Here, the two pieces to be joined are simply butted together in a similar manner to the butt joint in carpentry, but the adjacent surfaces are much more accurately fitted and are held in place by means of screws or dowels—the former when the pieces are broad and thin, as in Fig. 1 (*a*), and the latter when the timbers are heavy and thick, or when they are to be joined together on the thinner edges, as in Fig. 1 (*b*).

This simple form of butt joint in itself is insecure, and usually requires glue to make it in any degree reliable; or it may be kept in place by the woodwork against which it is erected, as would be the case in an exterior casing for a window. If the form shown in (*b*) is used, the top *h* should rest on the sides *j*.

The plain butt joint, shown in Fig. 1 (*a*), is seldom used in first-class joinery work, as the opening caused by shrinkage is very apparent. The absence of a device to keep the entire surface flush allows the fibers to curl, and the effect of shrinkage and warping would be to cause the pieces *c* to project slightly over the side of *d* and render the juncture too apparent. This may be obviated to a certain extent, when the grain runs parallel with the joint, by forming the joint as in (*c*); a quarter round *f* is worked on one of the pieces to be joined, thus forming fillets, as shown at *g*. The joint shown in (*a*) may also be doweled, as in (*b*).

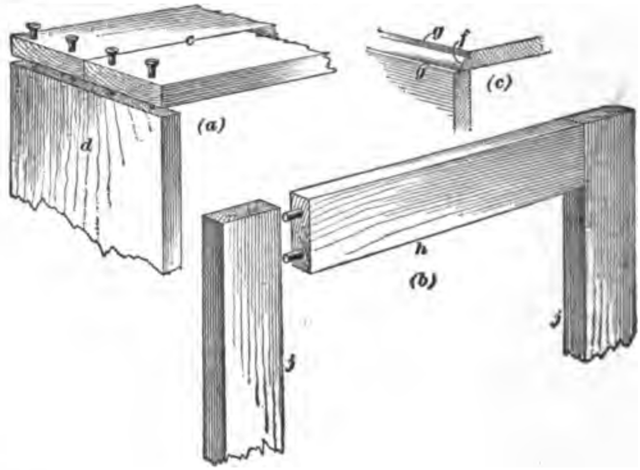


Fig. 1

7. Miter Joint.—The **miter joint**, shown in Fig. 2, is generally used when the boards are of the same thickness, where no great strength is necessary, and where the conditions require that the angle shall show no end grain of the wood, either inside or outside the joint. This joint is usually nailed or screwed together as shown, but depends on glue to make it secure, or is strengthened by a slipfeather, or spline, as shown dotted at *a*; it is also sometimes secured by gluing in a key of thin wood, which is inserted in a saw kerf cut diagonally, as at *b*, or at right angles to the end, as at *c*. A ***keyed miter*** is generally used for a joint seen only from the interior, as the keys disfigure the exterior. This joint is also made with the broad portion of the wood on the face, as in the case of architraves and casings.

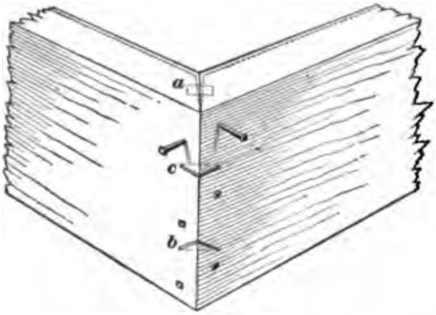


FIG. 2

In mitered joints, the shrinkage of the wood does not change the appearance of the exterior of the joint, but causes the interior to open slightly, as indicated by the dotted lines. To obviate warping, however, a tongue is very essential.

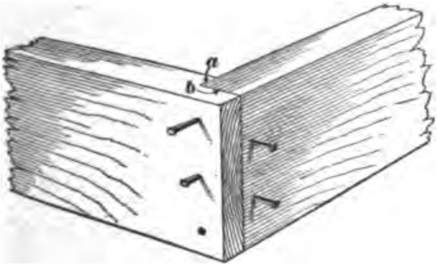


FIG. 3

8. Shouldered Corner.—The **shouldered corner**, shown in Fig. 3, is a joint used where the inside angle alone will be visible, and is an improvement on the butt joint shown in Fig. 1 (*a*), inasmuch as it provides two nailing surfaces, one at *a* and one at *b*.

9. Shouldered-and-Mitered Joint.—The **shouldered-and-mitered joint**, shown in Fig. 4, is a combination of the forms shown in Figs. 2 and 3. This joint has the advantage of showing no end grain as does Fig. 3, and possesses the additional strength secured in the method of joining the pieces of Fig. 3. The use of this joint, however, is limited to light work, where great strength is not needed, and is especially serviceable where a miter joint is required between pieces of unequal thickness, as in Fig. 4.

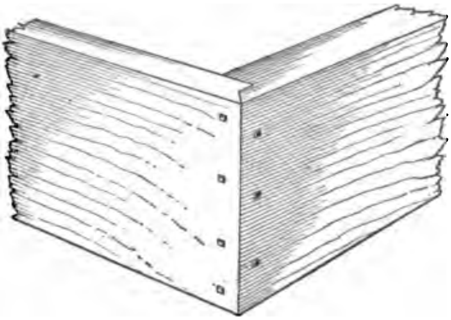


Fig. 4

10. Tongued-and-Grooved Joints.—The **tongued-and-grooved joint**, Fig. 5, the **dado joint**, Fig. 6, and the **housed joint**, Fig. 7, are all modifications of the same form, where the end of one piece is let into the side of another piece about one-third of its entire thickness. These joints are very frequently used in joinery. They are secured by means of glue, nails, or screws, or may be left loose to allow the members to come and go in shrinking and swelling.

In joining the back and sides of a drawer, the forms shown in Figs. 6 and 7 are frequently used, as the projection of the sides of the drawer, as from *e* to *d*, renders the end less likely to be pulled off by the jar of the contents when the drawer is suddenly opened; and any unequal shrinkage of the two pieces will not tend to split the material, provided the joint is not secured by too many nails.

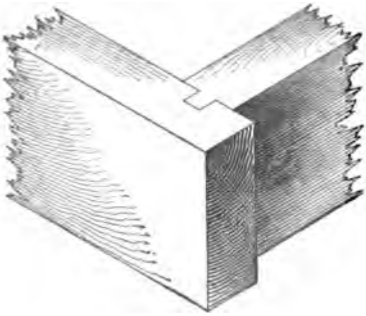


Fig. 5

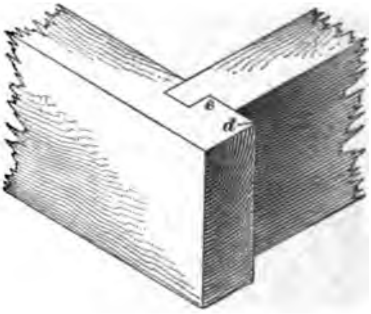


Fig. 6

11. Dovetail Joint.—The **dovetail joint** is one of the most important in joinery; it furnishes a rigid method of securing pieces together where the fibers of the material are approximately at right angles to the joint.

On analyzing the conditions of strength existing in a dovetail joint, it is evident that the strength of the entire joint depends on the combined value of the dovetails, the same as a nailed joint depends on the combined resistance of the nails, or as a nut on a bolt depends on the aggregate strength of the threads for its holding power.

The extent to which this is true may be realized by considering wherein the strength of each dovetail lies. In Fig. 8 (*b*), the projections on the piece *b* are liable to fail by the shearing of the flare, or dovetail, on each side of the projection, the strength in this case depending on the capabilities of the wood to resist shear across the grain; while the projections on the piece *d* depend for their strength on the resistance of the flares, or dovetails, to the shear of the wood parallel with the grain.

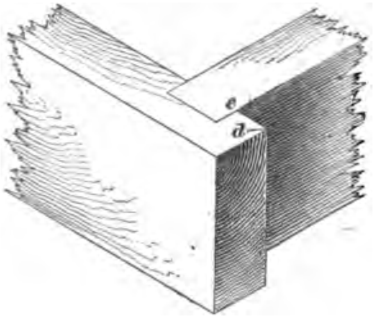


Fig. 7

The projections on the pieces *d* and *b* are also liable to fail by shearing through, or by breaking off where they join the main pieces of wood; consequently, the distance from *h* to *h* and the corresponding distance on the projections on the piece *b* should never be so slight as to be liable to break before the shearing strength of the wood across, or parallel with, the grain is realized.

There is still another factor entering into the strength of a dovetail joint, and that is the adhesive strength of the glue that binds the fibers of the projections on the pieces united, giving rigidity to the joint and preventing the piece *d* from pulling away from *b* in a direction parallel with the grain of the latter.

12. Dovetail joints are of three kinds. The common form, shown in Fig. 8, known as **lap dovetail**, has its dovetails on *d*, and its dovetail pins project from the body of the piece *b* a distance equal to the thickness of the piece *d*. The ends of the pins and dovetails show on opposite sides of the corner when the pieces are joined.

In preparing the dovetail joint, the pins *r*, Fig. 8 (*a*), are marked and cut first; the piece *e* is then laid across the end *f*, and the mortises *o* are carefully scribed with a knife point on the side of the end of *f*. The pins must be sawed square from the end, or parallel with the edge *t t*, Fig. 8 (*b*), and the mortises must be cut square across the end of piece *d*, as at *i i*, the greatest neatness and accuracy being required to insure good work.

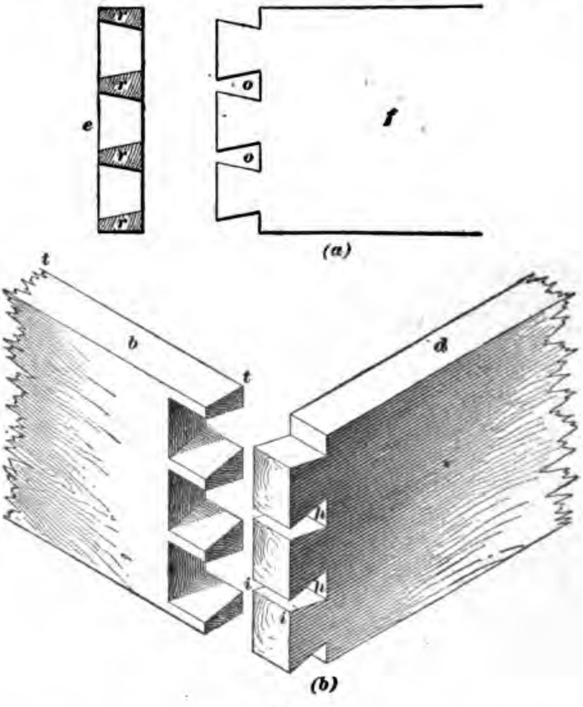
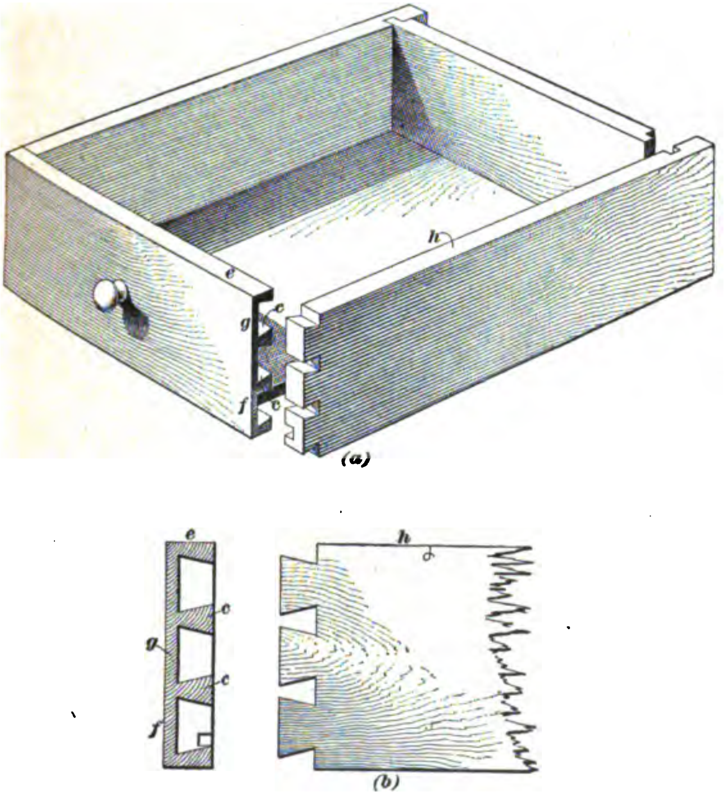


Fig. 8

13. Another form, known as the **half-lap dovetail,** is shown in Fig. 9. In this joint, the pins *c*, though cut down from the end of the board *e* a distance equal to the thickness of the board *h*, are not cut entirely through the board *e*, but have, as at *f*, *g*, a lap that covers the ends of the dovetails on *h* when the joint is closed. This entirely prevents the character of the joint from appearing on *e*, although the end grain of the pins *c* will show through the board *h*. This joint is well adapted for the fronts of drawers, as shown in (*a*), as the piece *e* that shows no dovetails forms the front of the drawer, and the ends of the dovetail pins on the side



(a)
(b)

FIG. 9

piece *h* are hidden when the drawer is closed. The side elevation of the joint and the relative size of the dovetails and dovetail pins are shown in (*b*). The reference letters refer to the same details in both (*a*) and (*b*).

14. The third form is known as the **blind,** or **secret, dovetail,** and is shown in Fig. 10. In this joint, about three-fourths of the thickness of the board is dovetailed, the remaining portion being united in a miter joint. Both the dovetails and the dovetail pins are here cut only partly through the board. The upper pin *a'* of piece *c* is cut off on the miter line of the angle, while the upper half of mortise *b'* is cut only to the miter line of the piece *d*, thereby concealing entirely the details of the true character of the joint when the pieces are united.

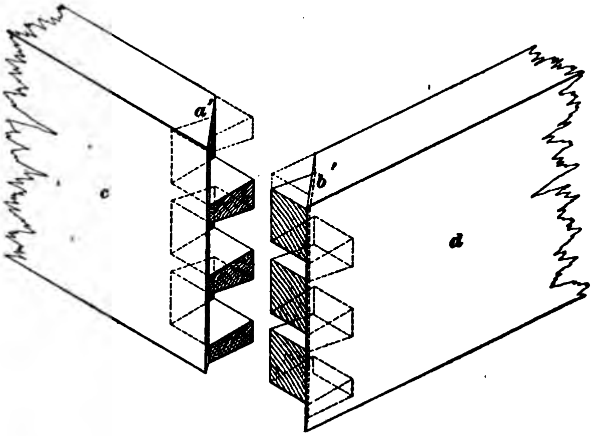


Fig. 10

This joint is seldom used in joinery, except for the front corners of highly finished drawers and boxes, where, for the sake of appearance, it is better for the dovetails not to show. The blind dovetail is not so strong as either of the other forms, partly because it utilizes only a portion of the available thickness of the wood, and partly because, on account of their concealment, it is impossible to see whether the pins and mortises fit one another accurately.

15. Machine Dovetailing.—Fig. 11 shows two forms of dovetailing that are executed by machinery. The form shown at (*a*) and (*b*) is used for the same purposes as that shown in Fig. 9, namely, for drawers, cabinets, etc., while that shown at (*c*) is used principally in making small boxes and filing cases, household articles, etc., and may be used with or without glue.

16. Doweled Joints.—The **doweled joint**, shown in Fig. 12, consists of a plain butt joint between the two pieces *e* and *f*, either between one end and a side, as in (*a*), or between the two meeting edges, as in (*b*). Holes are bored, and dowels are glued and inserted as shown. The object of the dowels is to keep the faces flush, and to render the joint stiffer if subjected to a transverse strain. The holes should be somewhat deeper than the length of the dowels, to allow for shrinkage of the material and at the same time insure a close joint. The form shown in (*a*) is a substitute for a mortise-and-tenon joint, but is not to be recommended.

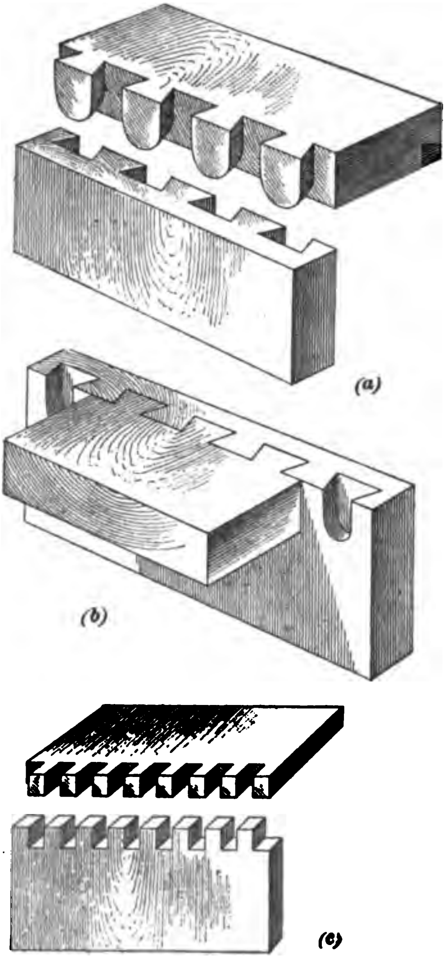


Fig. 11

17. Mortise-and-Tenon Joint.—The **mortise-and-tenon joint** as used in joinery is precisely the same in principle as the same joint in carpentry, but the fitting is much more accurate. This joint, in varied forms, is used to secure the rails and stiles of doors and windows, to unite the members of heavy machine frames, and to connect the various parts of tables, chairs, and other pieces of furniture.

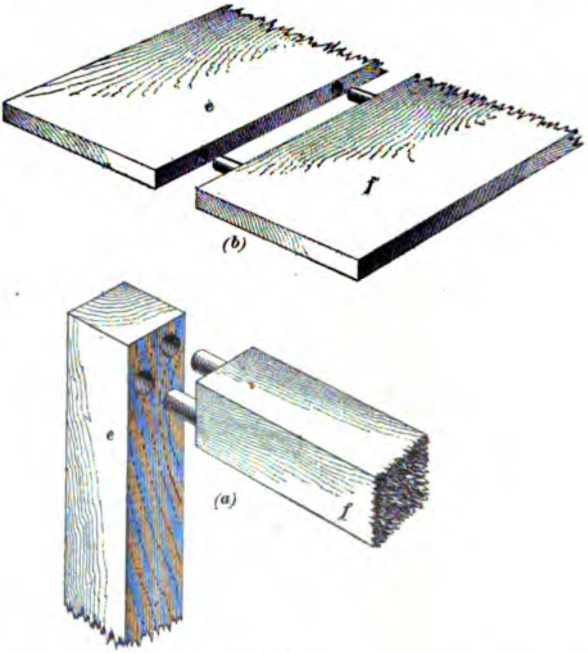


FIG. 12

18. Keys and Keying.—When broad, plain surfaces, such as dados, window backs, table tops, etc., are required, the boards forming them are generally tongued and grooved together or are doweled and united with glue; but, to secure the surface against warping or twisting, pieces of wood called **keys** are let into a dovetailed groove in the back, as shown at *a*, Fig. 13. These keys are either planed off flush with the surface into which they are sunk or, when extra strength is required, they may stand up from the back, as shown at *b*. Keys should not be glued in position, but are sometimes secured with a single screw or nail at one end, as shown at *c*, so that when the material shrinks it will slide on the key, and the joint along the keyway, or groove, will still remain tight.

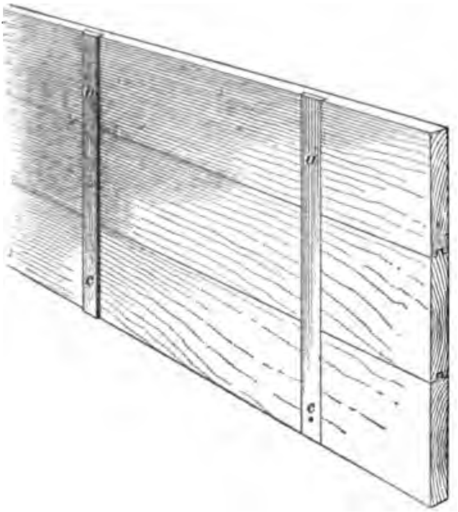


Fig. 13

19. Clamping. Boards are sometimes kept from warping by means of **clamping,** as shown in Fig. 14. The boards *a*, *b* are doweled or tongued and grooved together on their interior edges to form a close joint, as at *c d*, and the clamps *h*, *j* are glued over tongues worked on the ends of the boards, as shown at *e*.

In first-class work, tenons *f* are also worked on the boards *a*, *b*, and by insertion in the mortises in the clamp *h* strengthen the joint materially. When it is undesirable to show the end grain of the clamp, as at *e*, or of the tenons, as at *f*, the ends

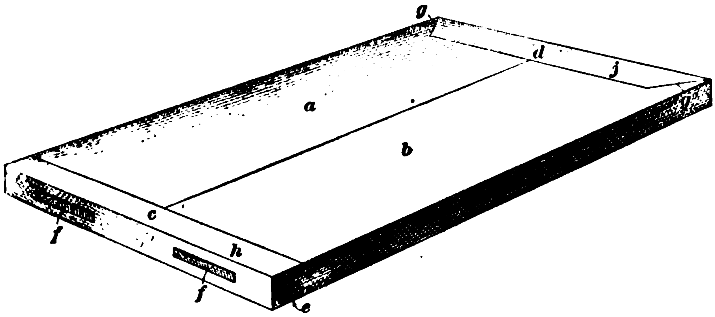


Fig. 14

of the clamps are mitered off, as shown at *g*, and the tenons are not permitted to extend entirely through the clamp.

Tenons and mitered clamps can only be satisfactorily used when the material is thoroughly seasoned and where the finished product will not be subjected to changes in temperature, as these connections furnish no provision for expansion and contraction.

20. **Marking Joinery Work.**—In all joinery work, face and edge marks are made so as to distinguish the face and the edge from which all measurements must be taken and all squaring done. At the same time, these marks serve to assist the joiner in determining the edges that are to be in contact, and prevent mistakes due to putting the pieces together improperly.

GENERAL JOINERY

PROVISION FOR EXPANSION AND CONTRACTION

21. All joinery work that is not framed, or "built up," should be so fixed that it is free to expand and contract. In a broad surface, such as a plain wainscot, this is accomplished by securing one edge only and permitting the other to rest in a groove, but in such a position that it may contract as the wood shrinks, or expand when affected by dampness.

All wood is subject to a change in width across the grain. When both edges are secured, shrinkage will cause the wood to split, and when dampness causes it to swell, it will either bulge in the middle or push out the securing nails or screws.

It may here be noted that a thorough knowledge of the properties of various woods is even more important in joinery than in carpentry. The slightest tendency of the material to warp, shrink, or swell must either be counteracted or prevented; for, however well seasoned the wood may be, it will always shrink somewhat across the grain when exposed to the warm, dry atmosphere of a dwelling house, and unless properly secured, thin panels will surely warp. For this reason, narrow boards are always preferable to wide ones, as the shrinking is distributed over a larger number of joints and is less noticeable; and, if the narrow strips are properly placed with respect to their original position in the tree, the tendency to warp may be largely overcome.

INTERIOR TRIM

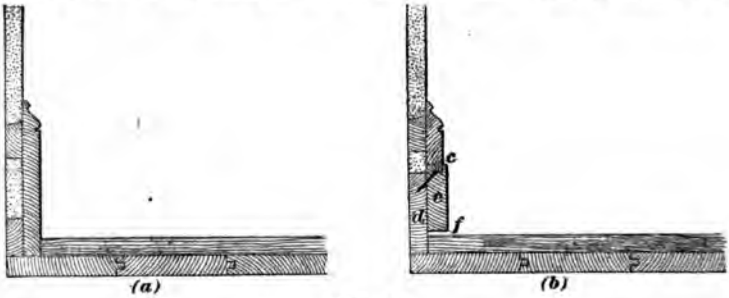
22. It is the work of the joiner to apply the door and window casings, baseboards, or skirtings, wainscoting, chair rails, paneled jambs, etc., and to hang the doors, sashes, transoms, etc. that fit into the openings he has trimmed or cased. Grounds should be placed by the carpenter around the margins of all openings, along the lower edge of the side walls, and wherever necessary to attach any portion of the interior trim, as thereby a straight and rigid base is secured for the attachment of the trim and also prevents the breakage of the plaster adjacent to the trim while the trim is being nailed in place.

23. **Architrave.**—The term **architrave** is given to a casing that has a back band and is used around door and window openings and so placed as to conceal the joint between the wooden ground and plaster. Thus, in Fig. 28 (*b*), *c* is the architrave covering ground *a* and plaster *b*. Architraves are sometimes richly molded or elaborately carved, but, except in specially designed work, it is considered better taste to keep them as simple and plain as possible.

24. Where architraves or simple casings extend to the floor, they must be thick enough to receive the end of the skirting *c'*, or they may stand on *plinth blocks a*, Fig. 20, that project beyond the casings and form both a base to the door trim and a stop for the skirting *c*. The architrave is attached to the ground *a*, Fig. 28 (*b*), after the plastering is thoroughly dry, and is so placed that its outside edge will extend well over and cover the joint between the plastering and the ground.

25. The upper corners of the architrave may be joined in several ways. They may be mitered, as shown at *e*, Fig. 28 (*a*), or, when the surfaces are plain, they may be butted, as shown in Fig. 28 (*f*). When the architrave or casing consists of both plain and molded surfaces, it may be joined by both butted and mitered joints, as shown at (*g*). In good work, the corners are mitered and grooved for a wooden tongue made of end wood glued in place. This groove, if made at the factory, is cut with a circular saw, and the wooden tongue is segmental in form to follow the outline of the saw cut. Sometimes, in cheaper work, corner blocks are used to stop the trim against, as shown at (*h*). These, however, are not to be recommended, not only on account of their inartistic appearance, but also on account of their tendency to shrink and leave unsightly cracks on both sides of the doorway. The architraves should be securely nailed both to the ground and to the jamb or lining all around the opening.

26. Skirtings.—The **bases,** or **skirtings,** of a room consist of a band composed of one or more boards from 6 to 18 inches wide, running around the bottom of the walls, to protect the plaster. The skirting board may be plain, or it may have a molding worked on it, as shown in Fig. 15 (*a*), or it may consist of a plain board with moldings applied independently to give it a finish, as shown in (*b*).



(*a*) (*b*)

Fig. 15

When the skirting is very wide and is made up of more than one width of boards, it is sometimes desirable to have the lower member *e* project beyond the upper one, thus forming a sort of plinth around the room, as shown at *e*, Fig. 15 (*b*). The clearance at *f* should be from $\frac{1}{8}$ to $\frac{1}{4}$ inch in rooms that are likely to be carpeted, so that the edges of the carpet when being laid may be pushed under the skirting board. When floors are finished with parquet work, etc., the joint between the base and the floor should be as close as possible.

27. Dados and Wainscots.—In rooms where the position of the furniture is frequently changed, such as dining rooms, kitchens, libraries, etc., as well as in bathrooms, halls, stairways, etc., it is sometimes desirable to affix a broad band, or molding, against the wall, about 3 feet from the floor and parallel with the skirting, to prevent the backs of the chairs from marring the plaster, and at the same time to form a cap to the dado, or wainscot, if such is desirable. This *chair rail* is affixed to a narrow ground, and should, of course, cover the joint between the ground and the plaster. The space between the chair rail and the skirting is called the **dado, or wainscot**; it may be paneled in wood, covered with narrow lining, or simply left plain in plaster.

28. In a paneled wainscot, such as is shown in Fig. 16, great care is necessary in fitting all the joints, and due consideration should be given to the subject of shrinkage, so that the subsequent drying out of the material will not cause unsightly cracks or open joints. The vertical pieces *a* and the horizontal members *b*, *b'*, and *b''* dividing the surface of the wainscot into panels, called *stiles* and *rails*, respectively, are framed and glued together. The panels *c* are left free to shrink or swell to a greater or less extent, without disturbing the surrounding members. The end stiles *a'* extend from the floor to the upper edge of the top rail *b*, and are mortised to receive the tenons of the rails *b*, *b'*, *b''*, as shown at *e*, *e'*, and *e''*. The rails are also mortised, and receive the tenons of the intermediate stiles, or muntins, *a*, *a''*, as shown at *f*.

In the edge of each stile and rail, a groove is worked to the depth of the molding *g*, and the edges of the panels *c* are either beveled off or hollowed out and then inserted into this groove, as shown at *h*. When small, the moldings *g* may be worked on the edges of the stiles and rails, but when large and heavy they must be worked from separate stock and fitted in position afterwards.

The panels are thus practically separate from the surrounding frame, and are free to shrink without danger of splitting. At the same time, since the amount of cross-grain in the extent of the wainscot is equal only to the sum of the widths of all the stiles in one direction and to the widths of all the rails in the other direction, the shrinkable material is reduced to a minimum, so that the wainscot, when constructed with well-seasoned material, will give good results.

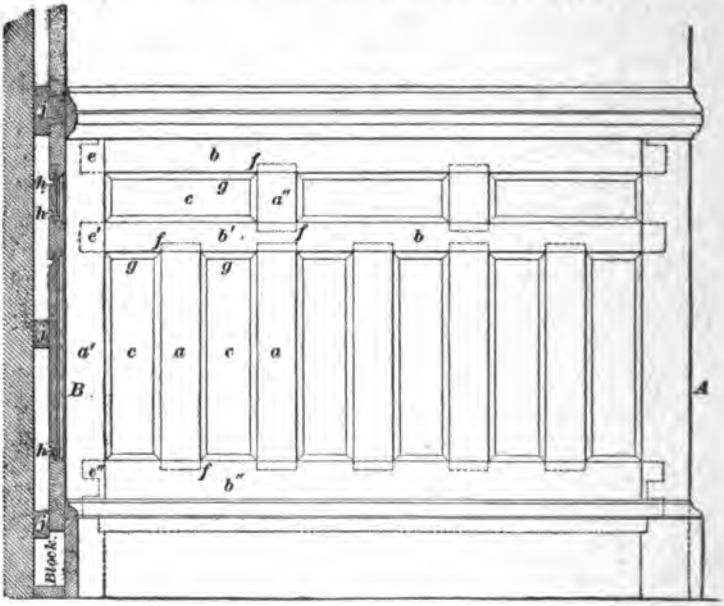


FIG. 16

29. Where the face of the wainscot is to be a plain, unpaneled surface of wood, still further precautions must be taken to guard against the effects of shrinkage and warping. Two general methods are recognized as satisfactory for this purpose. One is to make the wainscot of narrow boards, not more than three times their thickness in width, with the grain in each piece reversed with reference to that of the adjacent one; that is, to have the heart side of the material show on each side at every second board. After being tongued and grooved and glued together, the boards are secured against warping by keys inserted as described in Art. **18.**

The other method is to build the wainscot with several thicknesses of thin stock, reversing the grain in each piece. This method is the better one for long, unbroken surfaces, as shrinkage is prevented almost entirely; but, when the design of the wainscot will permit the building of a stile, or pilaster, every 6 or 8 feet, the narrow, keyed boards will be found to serve very satisfactorily, provided a ½-inch space between the ends under the pilasters is left to allow for expansion and contraction. These keyed sections, if the grain runs vertically, should be secured to the wall only in the center of their lengths, and left loose the rest of the way to come and go with atmospheric changes. If the grain runs lengthwise of the wainscot, no stiles, or pilasters, will be required to cover the joints, as the wainscot can be built up of one continuous piece; but the shrinkage between the base and the coping, or surbase, must be provided for, and the wainscot should be secured only in the center of its height, so as to allow the top and bottom to come and go.

30. After the paneling of the wainscot is completed, it is secured to the grounds, shown at *j*, Fig. 16, which are set in place to receive it, before the plastering is applied. Every possible precaution must be taken to insure the drying of the plaster, as the presence of the slightest moisture is disastrous to permanent joinery work. Under the most favorable conditions, at least a week should be allowed to dry each of the first two coats of plaster, and the hardwood trim should not be applied for two weeks after the finished coat is spread. In damp or rainy weather much more time should be allowed. The patent prepared plasters and wall cements dry in less time than this, and a deduction can be made when these are used, according to the rapidity of their drying.

31. When the wainscot is secured horizontally through its center, and allowed to shrink at the top and bottom, a horizontal ground must be provided to nail it to, and additional grounds must be provided at top and bottom to secure the coping and the base, as well as to form a backing for the upper and lower edges of the dado. When the wainscot is secured along vertical lines every 8 or 10 feet of its length, vertical grounds must be provided in addition to the grounds at top and bottom.

32. In laying out and spacing the stiles, rails, and panels of a wainscot, it is first necessary to prepare a long measuring rod, about 2 inches wide, through the center of which a line is drawn, as shown at *a b* in Fig. 17. The rod is then divided into a number of spaces, corresponding to the widths of the stiles and panels on one side of the line, and to the width of the rails and length of the panels on the other side; that is, the divisions in Fig. 17 that are above the line *a b*, as *c d*, *l m*, *l' m'*, etc., show the location and widths of the stiles *a* in Fig. 16, while the large divisions, as *d l*, *m l'*, etc., show the width of the panels *c*. The divisions *e f*, *g h*, and *i k* below the line *a b*, Fig. 17, mark the widths of the rails *b*, *b'*, and *b''*, Fig. 16, and the spaces *f g* and *h i* show the width and the length of the panels.

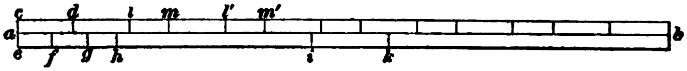


FIG. 17

The three rails *b*, *b'*, *b''*, Fig. 16, are clamped together with hand screws, and the rod is then used to lay out the width of, and the spacing between, the stiles. These divisions are then squared across the three rails with a square, and marked with a scratch awl or the point of a knife. The stiles are then marked in the same way, three or four at a time, and an allowance is made for the length of the tenons on the ends. In laying out the measuring rods for the spacing of the stiles and panels, it should be remembered that a stile must exist on each end of the wainscot, and to determine the number of panels required, the width of one stile and twice the thickness of the wainscot must be subtracted from the length of the room, if the wainscot returns on two interior angles, and the remainder divided by the sum of the widths of one panel and one stile. If, however, the wainscot returns around one exterior and one interior angle, as at *A* and *B*, Fig. 16, only the width of one stile should be deducted.

33. In Fig. 16, the length of the wall along which the wainscot is built is 3 feet 11 inches, and the panels are each 4½ inches wide; all the stiles are 3 inches wide, except the end one *A*, which is 3½ inches wide. If, now, 3½ inches, the width of the end stile, is subtracted from 3 feet 11 inches, the length of the wall, 3 feet 7½ inches of wainscot remains to be divided into six equal panels and six equal stiles. The combined width of a panel and stile, therefore, is 43½ inches ÷ 6 = 7¼ inches. Since the stiles are to be 3 inches wide, then 7¼ − 3 = 4¼ inches is the width of each panel opening. If the wall at *A* had returned on an interior angle, like the wall at *B*, the end stile at *A* would have been of the same width as the stile at *B*, and it would then have been necessary to deduct 3 inches, the width of one stile, plus 2¼ inches, twice the thickness of the wainscot, from 3 feet 11 inches, which would give about $6\frac{31}{32}$ inches as the width of each panel and stile combined; and, allowing 3 inches for the stiles, each panel opening would be $3\frac{31}{32}$ inches in width. The panels themselves, however, will be wider than that, as a proper allowance must be made all around for their insertion into the groove, as shown at *h*.

34. After all the mortises and tenons are cut and fitted, and each has been marked so that it can be returned to the same place to which it was fitted, the pieces of wainscot are taken apart and laid in a pile preparatory to gluing. Either the shoulders and cheeks of the mortises near the shoulders or the tenons near the shoulders receive the glue, and the stiles are forced into the rails as soon as possible after the glue is applied. The lower stiles are glued in the bottom rail first; then, their upper tenons are covered with glue in the same manner, and the middle rail *b′* is forced over them. The upper stiles are then glued into the middle rail. Finally, the top rail *b* is glued in place, and the whole form is drawn together with bench clamps until the glue is thoroughly dry.

35. In all joinery work framed together with mortise and tenon, care should be taken to clean out the mortises thoroughly and to dust off the tenons before gluing. Each tenon must be tried in the mortise to which it belongs, and any unevenness should be removed so as to insure a proper fit. All framed work should have its parts heated thoroughly before being clamped and glued together. If, when a piece of work is being clamped up, any rail or stile has a tendency to warp, then that rail or stile must be clamped in place with a bench screw under a piece of thick plank, and must remain this way until the glue is dry. Care should always be taken that an extreme pressure of the clamps does not cause the work to deflect, or wind, as it is exceedingly important in all kinds of paneled work that the whole face of the frame be kept in place, out of wind, until the glue is thoroughly set, or dry.

DOOR DESIGN AND CONSTRUCTION

36. A **door** is a simple piece of paneled work, but the great variety of form and arrangement of its panels and the enrichment of its moldings, together with the conditions arising from its method of opening or closing, require it to be even more securely framed and glued than a wainscot or other piece of fixed paneled work. The swinging of a door on its hinges brings a great strain on the joints in the stile on the hinge side, whereas a sliding door hung from the top has its entire weight suspended.

37. Sizes of Doors.—The width of a door is regulated by the purpose for which it is intended, so that in public buildings provision is made for the free passage of several persons at the same time, while in private houses and offices a width suitable for one person is considered sufficient. In the former case, the width may be from 6 feet upwards, while in the latter, the general rule places the minimum width at 2 feet 8 inches for communicating doors and 2 feet for closet doors. Where a folding, or hinged, door must be more than 4 feet wide, it should be made double; that is, in two folds. Since double folding doors in apartments take up considerable wall space when opened, it is preferable to substitute sliding doors, or doors that slide into pockets provided for them in double partitions. The proportion between the width and the height of doors at main entrances and in public buildings is usually 1 to 2, that is, the height is equal to twice the width, this being the rule adopted in classic structures. For single doors in dwellings and offices, the proportion should be as 1 is to $2\frac{1}{2}$; that is, the height should be equal to $2\frac{1}{2}$ times the width. Doors 2 ft. 8 in. × 6 ft. 8 in. and 3 ft. × 7 ft. 6 in., which are standard sizes, are thus proportioned. Where there are several doors of different widths in the same apartment, it is better to fix the height of the principal doors by the proportion given and make the others of the same height, which gives a better effect to the interior treatment. Where the width of double folding or sliding doors does not exceed 6 feet, their height may be that of the principal doors, but where wider than this, their height should be made one-fourth more than the width; for example, a door 8 feet wide should be 10 feet high. The width that can be given to sliding doors, however, is regulated by the depth that can be secured for the pocket in the partition.

38. Construction of Doors.—As a door made of one wide board would shrink and warp too much, the expedient is adopted of matching several pieces together. These are held in place and stiffened with two or three bars on the back. Where such doors are over 2 feet 6 inches wide, it is necessary to further stiffen them with diagonal bars or braces to prevent them from sagging. Such doors are used in inferior situations in the dwelling, or in the workshop, but when well made are strong and durable.

The most serviceable door is one in which the framing is mortised and tenoned together and the surface between the inner edges of the outer stiles and the top rail is formed with matched-and-beaded lining, the outer stiles and top rail being grooved, or rabbeted, to receive the lining and the intermediate framing being this thickness less than the stiles. The paneled door is the most approved form for general use, and a great variety of beautiful effects are produced by the artistic treatment of molded framing and molded and relieved paneling and the materials of which it is constructed.

In this form of door, provision is made for the expansion and contraction of the wide portions of the woodwork, caused by changes of temperature, and the portions that are closely united are made narrow in width for this reason and also to secure economy in the use of material. The requirements to be fulfilled are a rigid structure that shall remain firm and compact under usage and yet be sufficiently light in weight to be readily moved. The width of the framing should be about one-seventh the width of the door, and the bottom rail about one-tenth the height; the thickness will depend somewhat on the style of finish and the class of lock to be used. If rim or surface locks are to be used, the door may be somewhat less in thickness than where mortise locks are required; thus, chamber doors may be 1¼ inches thick, if the former are used, but should not be less than 1½ inches for the latter.

39. Panels and Moldings.—The proportions of the panels and the details of the design of the panels and moldings of doors are subject to great variation. The lock rail, however, should always be in a position not too low for a person to be able to reach the lock without stooping, nor too high to grasp the knob without reaching. The standard height to the center of the knob of the lock has been fixed at 3 feet from the floor. The lock should be mortised into the stile either between the tenons of the lock rail or immediately above them, in order not to destroy these tenons when the lock is inserted. A preferable method is to put in a lock panel from 6 to 7 inches wide in place of the lock rail; this is accomplished by practically cutting the lock rail in two in the width and inserting a panel between the sections, as shown in Fig. 18.

The molding around the panels of doors may be a simple ogee worked on the edges of the stiles and rails of the framing, and when worked in this way is known as *solid-molded.* Moldings of any desired form may be inserted in the angle between the edges of the stile or rail and the panel, as shown in Fig. 20 (*b*), care being taken to see that the nails pass into the edges of the framing and not into the panels, as the shrinkage of the panels would pull the molding away from the framing. Such moldings in good work should be glued to the edge of the framing. When the moldings do not project beyond the surface of the framing, they are called *sunk-planted*, and when they do project they are called *raised-planted.*

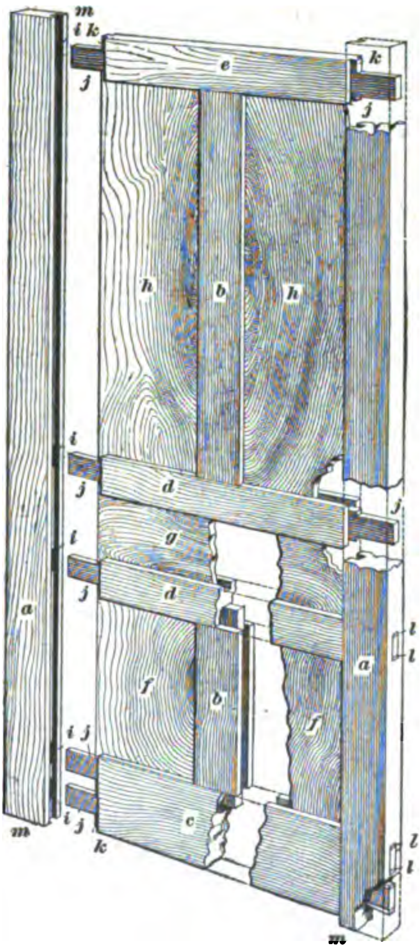


FIG. 18

40. Five-Paneled Door.—The mode of constructing a **five-paneled door** is shown in Fig. 18, in which certain parts are removed so as to clearly show the joints. The introduction of the lock panel provides for the insertion of a mortise lock without injuring the adjacent joints.

In this figure the parts marked *a* designate the outer stiles; *b*, the central stiles, or muntins; *c*, the bottom rail; *d*, the lock rails; *e*, the top rail; *f*, the lower panels; *g*, the lock panel; and *h*, the upper panels. The mortises *i* are made one-third the thickness of the framing, into which the tenons *j* are fitted. The edges of the framing are grooved $\frac{1}{2}$ inch deep to receive the panels, the width of the groove being the same as the thickness of the tenon. The upper edge of the tenons of the top rail and the lower edge of the tenons of the bottom rail are haunched, as shown at *k*, in order to obtain a compact mortise; otherwise, the stiles would be cut in two at those sections. The bottom rail has double tenons with a bridge between the mortises, which secures compact mortises and does not unnecessarily weaken the stiles. The central stiles are mortised into the rails. The panels must be kept from $\frac{1}{8}$ to $\frac{3}{16}$ inch less than the width of the space between grooves, as a provision for expansion. If the panels are fitted tight and the doors are put in place before the plastering is thoroughly dry, or the building is shut up for some time during damp weather, they will first assume a dishlike shape by expansion, or swelling, which if excessive will exceed the tensional value of the tenon and force the stile from its position by tearing the fibers apart.

41. Where the door is to be varnished, care should be taken to arrange the parts before they are assembled so that the grain of the timber shall be naturally placed; in other words, so that the leaf grain will be disposed to show an upward growth, and that in the panels will be adjacent to the center stiles. For fine work, straight-grained framing and curly panels give the best results, and a harmony of tone that is pleasing and agreeable is acquired.

42. In putting the door together, only the shoulder, or that portion of the tenon next to the panel, should be glued, so that in the event of shrinkage or swelling, the joints will remain close and intact. When the stiles are driven up and the cramps applied, the wedges *l*, Fig. 18, should be well fitted, should have their edges next to the tenons brushed with glue, and be driven in tightly. The horns *m*, or the extra lengths of the stiles during construction, are designed to withstand the pressure exerted when the end wedges are driven in. Otherwise, the wood beyond the mortise would be forced out by shearing of the fiber, thus destroying the joint.

43. Doweled Framing.—In some cases, the framing of paneled work is put together with dowels, as shown in Fig. 19. These dowels vary from $\frac{3}{8}$ to 1 inch in diameter, according to the thickness of the wood to be united, but in any case they are considerably thicker than a mortise would be in the same material. Along the edge of each dowel, a V-shaped groove is cut, as shown at *a*, to allow the air and surplus glue to escape when the parts are driven together.

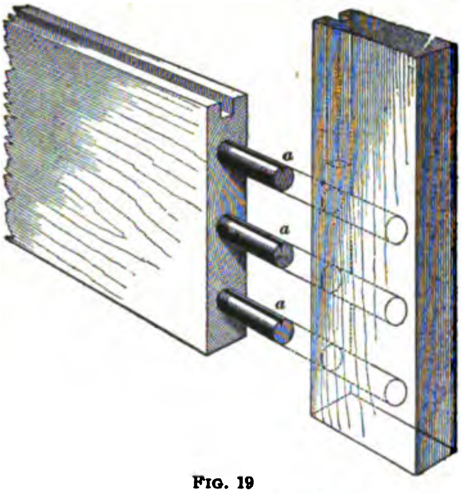


FIG. 19

44. Sliding Doors.—**Sliding doors** differ from ordinary swinging doors chiefly in the method of hanging them, and, as the strain of their parts is reduced or increased with the different methods, a corresponding alteration of the details of their framing is necessary. Fig. 20 (*a*) shows one of a pair of sliding doors, intended to be hung from the top. In a door hung in this manner, the stile is not subjected to such great strain as when the door is hung on the side. Where a sliding door is hung with the patent stile hanger, which brings the entire

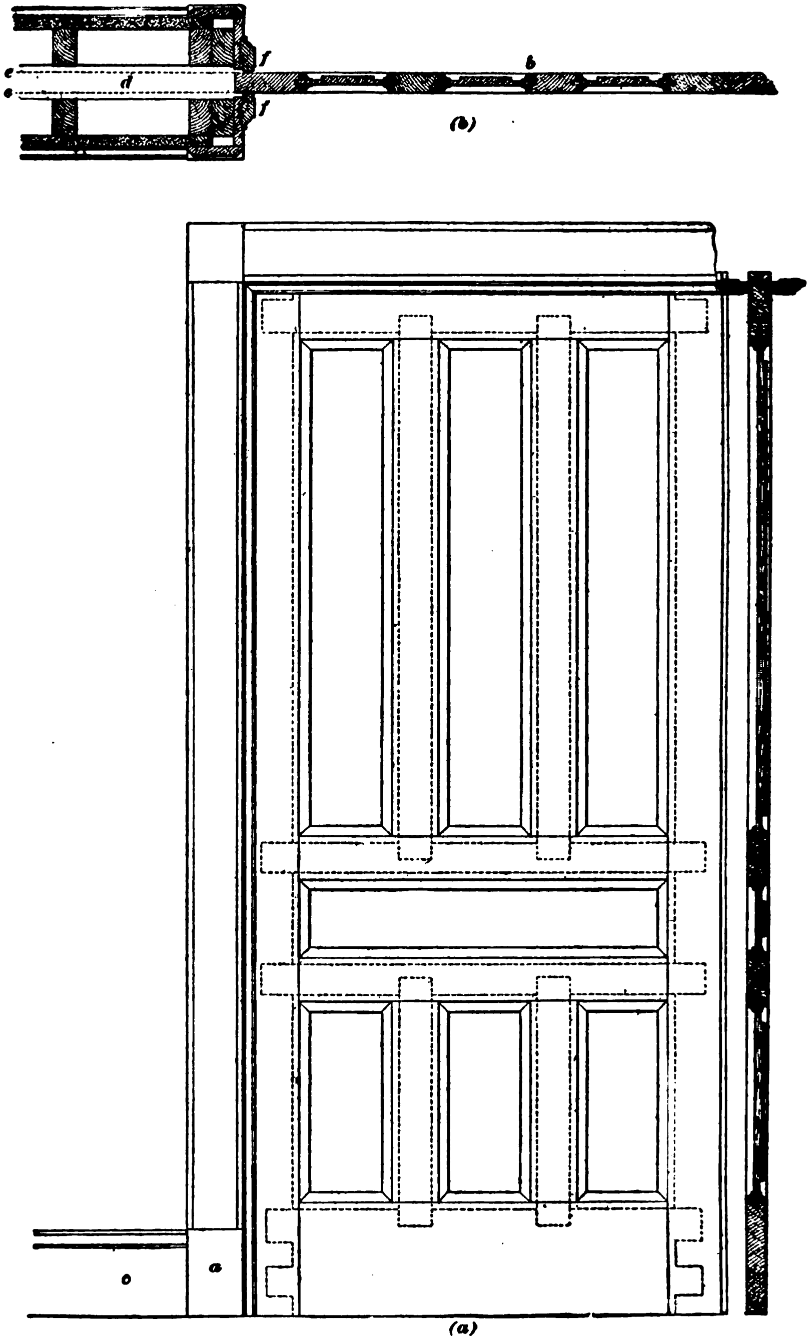


FIG. 20

weight on the stile, particular attention should be given the mortises and tenons in the hanging stile to insure a perfect fit, as the slightest loosening would cause a sag in the door and thus prevent it from running smoothly.

In the plan of this door, at (*b*), the meeting stiles of both doors are shown, and, as will be seen, the edges of the rails are worked to fit together in a shallow tongued-and-grooved joint. This preserves the alinement of the doors when closed, and tends to prevent the appearance of a slit, or crack, between them, as would be the case if they simply butted together.

In opening, the doors slide into a pocket *d* built in the partition, the dotted lines *e* showing the position of the door when it is in the pocket. This pocket is framed and finished in the same manner as a simple studded partition, except that the studs are set in two rows with a space between them, at *d*, about 1½ to 2 inches wider than the door is thick. The jambs of the door opening are then finished with a molded trim, which is let into the jamb, as shown at *f*, and is allowed to project over the end of the pocket to within ¼ inch of the door. A stop is provided within the pocket, to prevent the door from sliding too far into the opening. The hardware on the meeting stiles of the door must be sunk flush with the face of the stile, so that it will not prevent the door from sliding clearly into the pocket. Numerous sliding-door locks and catches, made especially for this style of door, are provided by the hardware dealers.

45. Folding Doors.—**Folding doors** consist of a pair of single doors hinged on opposite sides of the opening. They are provided with a stop-bead or a rabbeted stile, so that they will close together in a tight joint at the middle of the opening. Fig. 21 shows a plan (*a*) and an elevation (*b*) of a pair of folding doors arranged to meet the requirements of the outside vestibule-entrance doors, or *storm doors* as they are sometimes termed, of a frame dwelling. When this form of door is used as an inside vestibule door or a direct-entrance door, the panels *b*, as shown at *o* in the section B'', taken on the

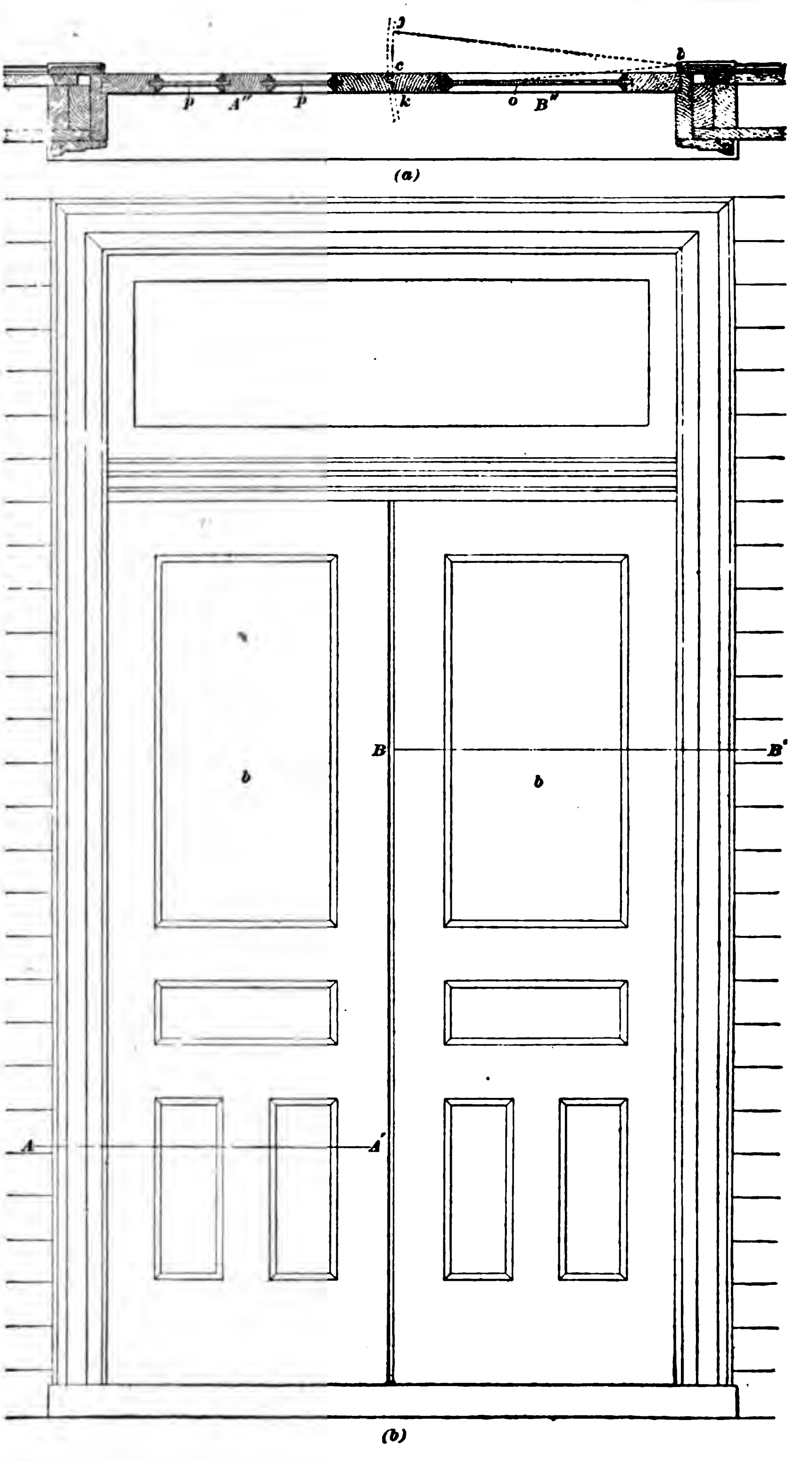


FIG. 21

line *B′ B* of the elevation, are usually of glass; but in the former case, the transom only may be glazed, so as to admit light to the vestibule when both doors are closed. The sectional plan *A″* of the door is taken on the line *A A′*, and shows the two lower panels at *p*. The framing of the stiles and rails of folding doors is precisely the same as for single swing doors, but the meeting stiles must be rabbeted, as shown at *c*, so as to provide a stop against which the more frequently used door may close.

This rabbeted stop must be beveled off slightly on the inside, to give proper clearance to the outside angle of the door when it is opened. The amount of bevel necessary in order to accomplish this clearance is found by striking a circular arc *j k* with a radius *k l* equal to the diagonal distance from the corner *k* of the door to be cleared to the center of the butt pin *l*, and with a center at the latter point.

WINDOW DESIGN AND CONSTRUCTION

46. In the construction of a building, the necessary window openings are arranged in the walls. These openings are subsequently to be provided with some form of window frame and sash. The particular form in each case will depend on the character of the building and the purposes for which the windows are required. In residence structures, the main object is to secure proper light and ventilation, and some form of sash window is used; while in stores and some warehouses, the first-story windows are usually arranged for the display of goods offered for sale, and the window assumes the character of a glass case without sashes or frames, except such as are necessary to hold the glass in place.

47. Area of Window Surface.—The following proportions are given by different authorities for fixing the amount of window surface: (1) One-eighth of the wall surface should be windows. (2) The area of glass should equal at least one-tenth of the floor area. (3) One square foot of glass should be allowed to 100 cubic feet of interior space to be lighted. It is better to have a surplus than a deficiency of light, for if too bright, the light can be regulated by blinds or shades.

48. Design.—The height of the window should be twice its width. Architraves should be from one-sixth to one-seventh the width of the window opening, and where pilasters adjoin architraves, their width should equal that of the latter. Where consoles are used, their length should not be less than one-third nor greater than one-half the width of the opening. The entablature should be from one-fourth to one-fifth the height of the opening. Where engaged columns flank windows, at least three-fourths of the column should project beyond the face of the wall.

To obtain a uniform frieze line around rooms in dwellings, it is well to keep the window and door heads equidistant from the ceiling. Thus, where the walls are 10 or 10½ feet high and the doors 8 feet high, the top of the casing is from 18 to 24 inches from the ceiling. This space may be occupied by frieze and cornice, or a picture molding may extend around the room in line with the upper edge of the door and window casings. Where ceilings are not over 14 feet high, this same effect can be obtained by introducing transom sash over the doors, filling these with either chipped plate glass or art glass.

The glass line of windows in dwellings should be about 30 inches from the floor for principal rooms and about 36 inches for bedrooms. In all cases, the heads of windows should be as near the ceiling as the construction and interior scheme of treatment will permit, to obtain better light and ventilation. The meeting rails of window sash should be placed not less than 5 feet 9 inches above the floor; otherwise, the rail will be on a level with the eyes, obstructing the view and detracting from the effect of the window. On this account, the height of the upper sash is sometimes made only one-half that of the lower, or one-third the clear height. For buildings of any pretensions, it is a mistake to cut up the sash into small panes. It should be remembered that windows are designed for the purpose of lighting, and all obstructions created by sash bars detract from the desired result. Where the designer prefers to have the window sash subdivided, metallic bars of zinc, copper, or lead will be found more durable than wood, and will not take up so much of the daylight area.

49. Window Sash.—Sash windows may be divided into two general classes; namely, **fixed sashes**, and **movable sashes**. The latter class may be hinged, pivoted, or balanced, as the case may require. Window sashes vary in thickness according to their size, but in ordinary frame dwellings they seldom exceed 1¾ inches. The frames for these windows are generally built in the walls as the building is carried up, and are differently constructed, according to the character of sash they are to carry and the material of the wall in which they are inserted.

50. Sashes should preferably slide vertically, counterbalanced by means of cord, chain, and weights, or by spring sash balances. Those which are hinged and open inwards cannot be made water-tight, and those opening outwards are likely to be injured by the action of wind, so that for general service the best results are obtained by use of sliding sash. Sash stops should be fastened with screws passing through slotted sockets, thus preventing the sashes from rattling and warping.

51. Window Frame for Frame Dwellings.—In Fig. 22 is shown a window frame for an ordinary frame dwelling, the various parts of which are as follows: In (*a*) is shown a section through one side of the frame, the stud at the side of the opening being shown at *a*, the exterior sheathing at *b*, the lath and plaster on the interior at *e*, the pulley stile at *g*, and the sash weights at *i*. At *f* is shown the exterior sash stop, against which is secured the exterior casing, or blind-hanging stile, *c*, which must be of the same thickness as the blinds. The exterior sheathing *b* is cut flush with the inside of the stud opening, as explained in *Carpentry*. The casing *c* is secured to the stud *a*, through the sheathing *b*, thereby keeping the pulley stile in its place on the outside, while the architrave, or interior casing, *j* performs the same function on the other side of the wall. The pulley stile *g* is plowed for the parting strip *h*, and in the groove thus formed, the parting strip is inserted as shown, forming a channel for the upper sash to slide in. The lower sash is hung on the inside of this parting strip, and is secured in place by a stop-bead *n*. The stop-bead and parting strip are secured in place on the pulley stile by means of nails or screws, but are left so that either may be readily removed, and the sash may thereby be taken out at any time if required. The parting strip may be kept in place simply by the tightness of its fit in the groove in the stile, but the stop-bead should be screwed to the pulley stile.

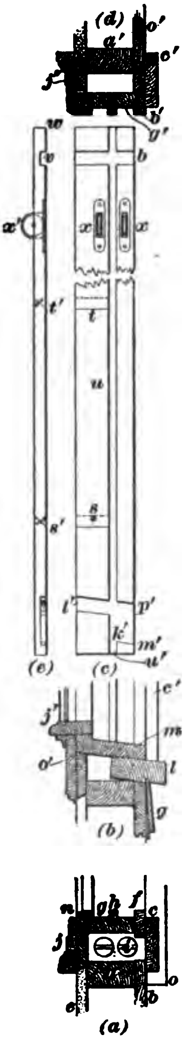


FIG. 22

52. In Fig. 22 (*b*) is shown a vertical section of the frame through the sill and other details of the lower part of the window. The sill *m* is inclined at a pitch of about 1½ inches to the foot, and its outer edge rests on the sub-sill *l*, which is inclined at a similar angle and has its under side grooved to receive the upper edge of the clapboards *g* or shingles covering the side of the house. At *o'* is shown the inside casing, or *apron*, as it is frequently termed, which is attached to the back of the sill *m* and which, with the sill cap, forms the inside finish of the lower part of the window. The inside casing, or architrave, *j'*, as shown in the sectional plan at *j*, rests on the sill cap shown over the apron *o'*. The sub-sill *l* receives the bottom of the window frame on the outside of the house; on it rests the exterior casing *c′*, which is seen in the sectional plan at *c*, and which frames the window opening on the outside in the same manner as does the trim *j′* on the inside. Both the sill and the sill cap are carried beyond the casings *c* and *j*, and are returned against the walls, as shown at *o* in the plan (*a*).

53. In Fig. 22 (*c*) is shown the elevation of the inside face of one of the pulley stiles. The lower part of the pulley stile *l′ m′* is cut out to receive the ends of the sill and sub-sill—the sill extending through the entire thickness of the stile from *l′* to *p′*, and the sub-sill extending from *k′* about 2 inches beyond the face of the stile at *m′*. The ½″ × ½″ groove plowed to receive the parting strip *h* is shown at *u*. The depth of the cut-out portion *l′ p′ m′ k′* is equal to the depth of the groove *u*, and as shown at *u′*, the groove extends to the bottom of the stile. The upper part of the pulley stile is grooved at *b* to receive the window head, immediately below which are placed the two pulleys *x*, *x*, one for each sash. These pulleys are let into the face of the stile so that the face plates are flush with the inside of the frame, but the wheels extend through to the interior, as shown at *x′*, in the side elevation (*e*) of the stile. The depth of the groove to receive the window head is ½ inch, as shown at *v*; the material from *v* to *w* extends 2 inches above the window head, to permit the fitting of the frame to the stud opening.

At *s t* in the elevation (*c*) is shown an opening to the weight box, known as the *pocket*. This opening is cut out to permit easy access to the weights, in case of renewal of the sash cords, and is closed by means of a bevel-edged board secured in place by screws. In the elevation of the pulley stile at (*e*), the pocket cover is shown at *s′ t′*, as well as the lines on which the ends are beveled to secure the desired fit. The upper bevel at *t′* is notched over the shank and under the head of the screw inserted in the back of the stile, as shown at *t′*. The lower bevel *s′* is then secured against the bevel of the pocket by means of a screw driven straight through the face of the cover, as shown at *s* in the elevation (*c*).

54. In Fig. 22 (*d*) is shown a section through the window head at the center of the opening. Here, the stud *a'* is shown in its position at the top of the frame opening, while the window head *g'* is shown 2 inches below; these 2 inches permit projections of the stiles, shown in (*e*) at *v w*, to be fitted to the top of the opening. The inside trim *j''* is then secured across the opening between the stile *g'* and the stud *a'*, and the outside trim *c'* is laid over the exterior casing *b'* and extends to the sheathing at the edge of the framed opening at *o'*. A cap member should be placed over the upper edge of the outside casing to shed the water, as shown in Fig. 33 (*c*), or a cap flashing of tin, copper, or lead may be turned up 2 inches under the siding, lapped over, and turned down an inch on the face of the casing, with the lower edge securely nailed.

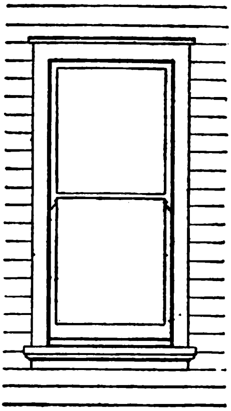


FIG. 23

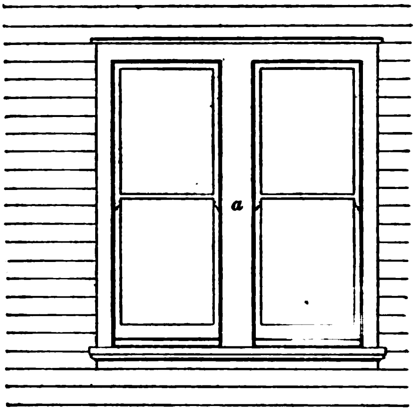


FIG. 24

This practically completes the description of the parts of the frame for any single window in a frame building such as shown in Fig. 23; when, however, windows are coupled in pairs or triplets, a dividing member *a*, Fig. 24, called a ***mullion***, must be included in the frame, as hereinafter described.

55. Construction for Wood Wall.—In Fig. 25 is shown a view of a window frame with sliding sash, adapted for a frame building. The pulley stile *a* may be from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches thick, and should be, though not always, tongued into the blind stop *b* and the plaster casing *c*, each of which is $\frac{7}{8}$ inch thick. These tongues make the stiles rigid, preventing them from deflecting sidewise when the sashes are being operated. An open space of from 2 to $2\frac{1}{2}$ inches is left between the back of the pulley stile and the rough stud, thus forming a box for the weights. A movable pocket for the insertion of the weights is cut out of the lower portion of each pulley stile on the inside, so that it may be covered by the lower sash. The parting strip *d* is $\frac{1}{2}$ or $\frac{5}{8}$ inch thick, and passes into a groove $\frac{3}{8}$ to $\frac{1}{2}$ inch deep in the pulley stile. The outside casing *e*, $1\frac{1}{8}$ in. thick × 5 in. wide, is firmly nailed through the $\frac{7}{8}$-inch blind stop into the pulley stile and to the $\frac{7}{8}$-inch wall sheathing. The inner face of the window frame is finished with a casing *f*, which may be of any style of finish—in this case, by an architrave, the width being sufficient to cover the plaster joint. The sash stop *g*, from $\frac{1}{2}$ to $\frac{5}{8}$ inch thick, is secured with round-headed screws passing through slotted sockets for adjustment. The members *g*, *d*, and *b* should be kept in line, their projection beyond the face of the pulley stile being regulated by the thickness of the sash stop.

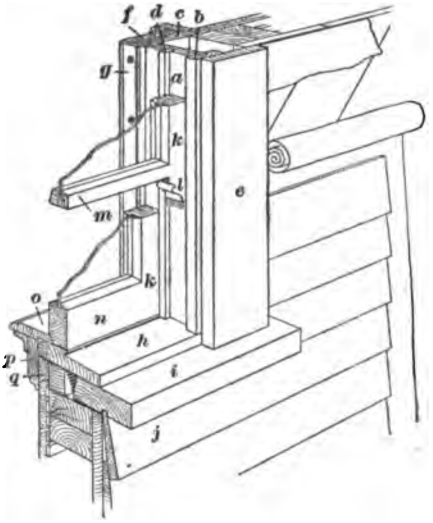


FIG. 25

The sill *h*, from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches thick, is tongued into the pulley stiles and well nailed. Sills are sometimes made with a straight, inclined surface instead of being worked with two fascias, as shown. When water collects on the sill, it is readily drawn under the lower rail *n* of the sash by capillarity, or it may be driven in by wind; by raising the surface under the sash above the level of the outer portion, and running a small, rounded groove in the fillet, the effect of the wind is to divert the water outwards. Under *h* is placed the subsill *i*, $1\frac{7}{8}$ inches thick, which is attached to the pulley stile and likewise grooved for the reception of the beveled siding *j*.

For durable work, the window frames should be put together with stiff white-lead paint, particularly adjacent to the sill and sub-sill. The sashes *k* are made from $1\frac{3}{8}$ to $1\frac{7}{8}$ inches thick. Strength is added to the upper sash by the elongation of the stile, forming a molded horn *l*, as by this device the tenon of the meeting rail *m* can be made to equal its thickness. The meeting rails, $1\frac{3}{8}$ to $1\frac{7}{8}$ inches thick, according to width of opening, may be double- or single-beveled, as shown, so that they will come tightly together when closed. The lower rail *n* may be from 3 to $4\frac{1}{2}$ inches wide, and should be accurately fitted to the sill; the outer edge should be clear about $\frac{1}{8}$ inch, but the inner portion should be in contact with the sill, thus preventing the ready passage of water. The inner face should be rabbeted and beveled to fit the edge of the stool *o*. The stool should be rabbeted to form an air-tight joint and should be bedded in white lead. An apron *p* is fixed to the edge of the sill and a plaster ground *q*, and is finished with a bed mold as shown. The length of the apron should be equal to the width from out to out of casings, and have the moldings returned on same.

56. Construction for Masonry Wall.—In Fig. 26 is shown a **box-frame window** suitable for a stone or a brick wall. The general design and construction of the frame and sash are similar to that shown in Fig. 25, the only changes being in parts that must be adapted to a new condition.

In brick walls it is customary to set the window frames during the erection of the walls, thus facilitating the plumbing of the brick jambs, particular care being taken to brace the frames in order to keep them plumb and level. By keeping the blind-stop casing *a* 1 inch wider than the ⅞-inch back lining *b*, the frame can be firmly held in place after the braces are removed. The sill *c*, made of 3-inch plank, is (or should be) bedded in haired lime mortar, or, for first-class work, stiff white-lead paint and white sand. The groove in the bottom of the sill permits the formation of a mortar tongue, making the connection practically air-tight. Unless this device is adopted, the slightest shrinkage or warping of the sill allows the passage of air and water. A ½-inch finished casing *d* may be attached to the inner ⅞-inch frame casing *e* after the building is ready for trimming, thus covering its marred condition. The window stool, or seat, *f* rests on furring strips and is tongued into the sill, thus providing for its expansion and contraction. The stool is generally finished with a molded apron *g*. The jamb lining *h* is tongued into the finished casing, and the opening is trimmed

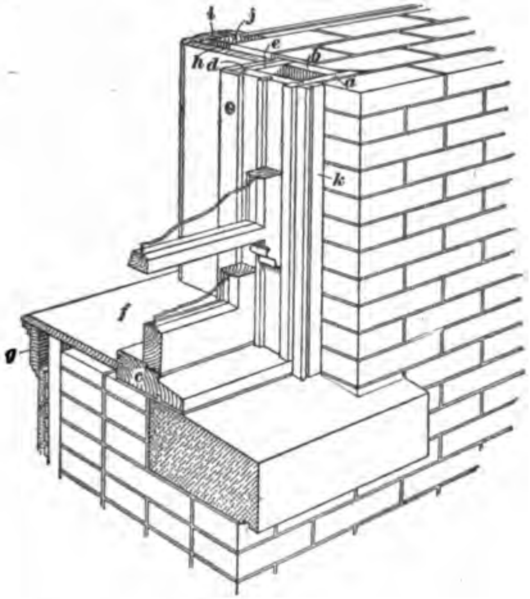


FIG. 26

with a casing, as at *i*, nailed to the lining *h* and the rabbeted plaster ground *j*. A hanging stile *k* in brick-set frames is attached before setting, but where outside blinds are not used, an angle mold may be substituted.

57. In stone walls, window frames are not usually set until the building is roofed and is either prepared for the plastering or has the plastering completed. There are two reasons for this, the principal one being the difficulty experienced in setting jamb stones and lintels while the frame is in position, and the second that, with all due care, the frames are more or less damaged during building operations and are never so true to line, level, and plumb as those set in place after the walls are completed. When set in this latter order, it is necessary to incase the masonry openings with screeds, or wooden strips, carefully alined and plumbed and so arranged as to allow for a bed of haired mortar $\frac{1}{4}$ inch thick around the jambs and window head. The frames are secured by means of holdfasts, or wall plugs. When set in this manner, the casing *d*, Fig. 26, is not required, unless the interior trim is of a material different from that of the window frame.

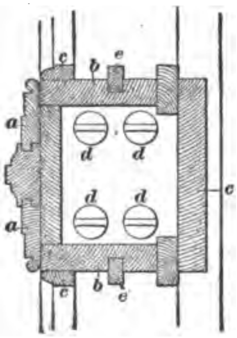


FIG. 27

58. Mullions.—A mullion is simply a division placed between two sashes. With sliding sashes, the mullion must contain the weight box, but with hinged sashes it need be no more than a bar against which the sashes may close or on which they may be hinged. The former kind is illustrated in Fig. 27, which shows a horizontal section through the mullion *a* in Fig. 24.

Inasmuch as the mullion may contain four weights (two for each pair of sashes), instead of two weights, as in the box of a single window, the inside trim *a*, Fig. 27, and the outside trim *c* must be somewhat wider than the same details are in a single frame.

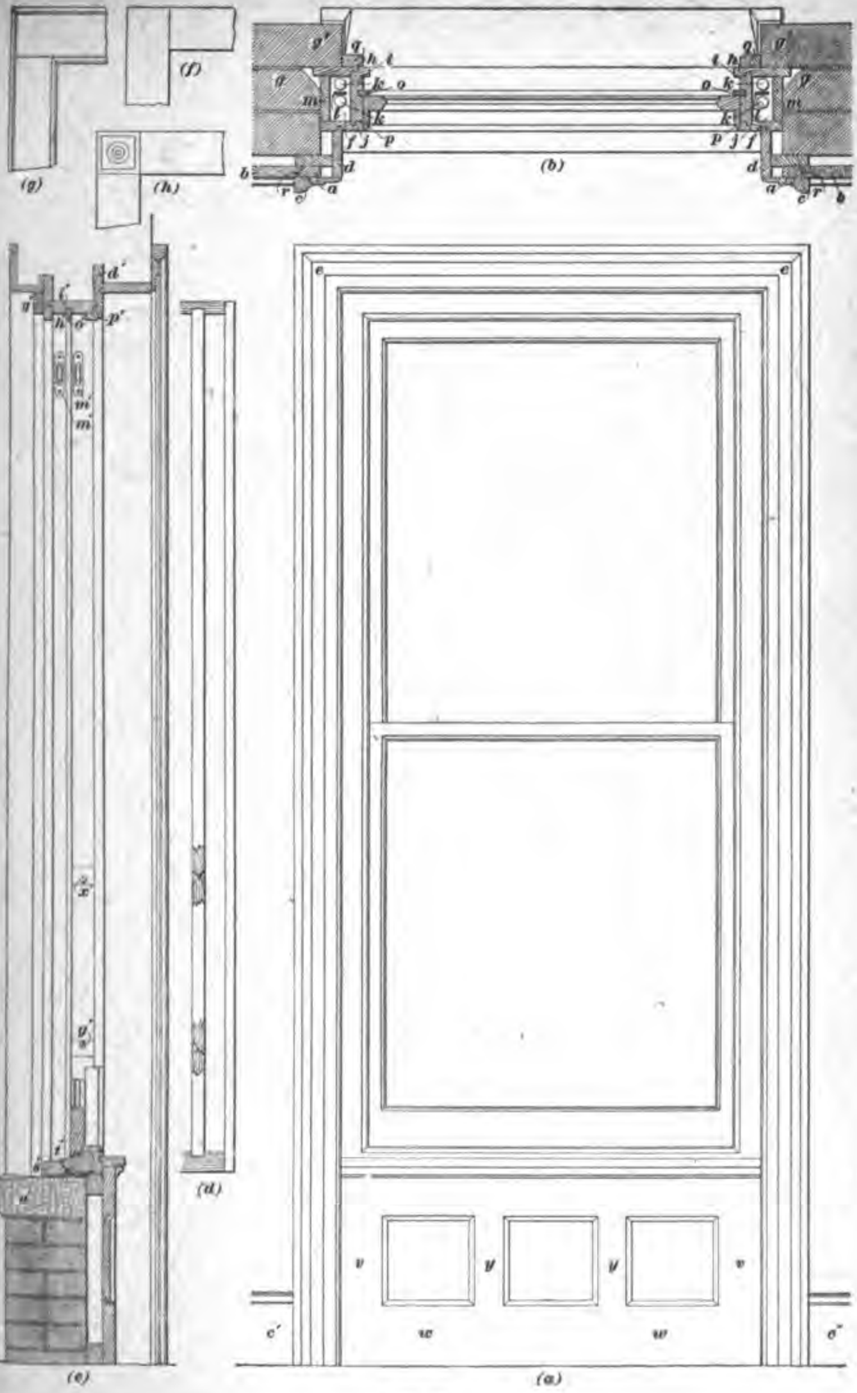

(g)
(f)
(h)
g′ q h i g m l f j p d b r c a o k
(b)
i h q g′ g m k o l p j f d a c r b
d′ g′ i′ h o′ p′ m′ m′ x′ y′ t′ s u
(d)
e e
v y y v
c′ w w c″
(e)
(a)

Fig. 28

The pulley stiles *b*, the stop-beads *c*, and the parting strips *e* are detailed in precisely the same manner as in a single frame, but as the distance between the stiles *b* is from 4 to 5 inches, in order to accommodate the weights *d*, the casings must be proportionately wider to cover the joints. The pocket in the pulley stile may exist on one side of the mullion only, as access to all four weights can thereby be readily attained. The sill of the window, however, is not gained into the pulley stile of the mullion, as is the case with the single frame shown in Fig. 22; instead, the sill and the window head each extend as one piece across both openings, and each is grooved to receive the mullion pulley stiles.

59. Window Frame With Interior Trim.—When a window frame is required for insertion in the opening of a brick or a stone wall to be subsequently finished on the interior, the details must be carefully considered in order to make the frame fulfil the requirements. Fig. 28 (*a*) shows the interior elevation of such a window; (*b*), a horizontal section; (*c*), a vertical section; and (*d*), a section through one of its pulley stiles. In the horizontal section (*b*), the weight boxes with the details of their construction are shown at *f*. The brick wall *g* is 12 inches thick, with a reveal at g' of 4 inches. At *h* is shown the outside lining, into a groove of which is tongued the pulley stile *i*, which in turn is, in a similar manner, let into the inside lining *j*. These three pieces form a box *f*, in which are hung the two sash weights *k*, sometimes separated by a wooden tongue *l*, so as to prevent them from striking together when the sash is raised or lowered. This tongue is only used when the weights are large, or the space for weights is limited. The weight box is closed by the back lining *m*. The pulley stile *i* is grooved to receive the parting bead *o*, which, with the ½- or ⅝-inch projection of the outside lining *h*, secures the upper sash in its place and provides a *way* in which it may slide. The parting strip may be of hardwood from ½ in. × 1 in. to ⅝ in. × 1¼ in. in section. The lower sash slides inside of the parting strip and is secured in place by means of the stop-bead *p*.

In the angle between the outside lining *h* and the brick reveal *g'* is placed a casing *q* to which outside blinds or shutters may be hung, though sometimes it is of some special design. The jamb lining *d* is secured to the inside lining *j* and extends to the floor; the architrave, or trim, *c*, is attached to it, and by covering the ground, binds the plaster joint at *r*.

The top of the window frame is shown in Fig. 28 (*c*). Here, the exterior casing, or angle mold, is mitered in the corner and is carried across the top of the window, as shown at *q'*, while the outside lining is butted in the corner and carried across the top of the opening, as shown at *h'*. The window head *i'* is let into the pulley stiles and plowed to receive the parting strip *o'*. The stop-bead *p'* is mitered in the angle and returned across the top of the frame, thus covering the joint between the window head *i'* and the inside casing *d'*. The pulleys *m'* are the same as in the former case, and the pocket, as shown at *x' g'*, gives access to the weights.

The outer edge of the sill *s'* rests on the stone sill *u'*. There is also a break, or step, in the thickness of the sill where the stop-bead meets it. When set, the sill is laid on a bed of mortar spread over the stone sill *u'*, and this mortar, being forced up into the groove shown at *t'*, makes a perfectly water-tight joint between the two sills.

From the sill to the floor, on the inside of the window, the wall is covered by a *panel back*, or breast, as shown in the elevation (*a*) at *w*. The stiles, rails, and muntins of this panel back are grooved on their edges and mortised and tenoned together, as are also the same details in the doors. The lower rail is scribed to the floor, and the upper rail is capped by the wooden sill of the window, as shown in the section (*c*). A molding is then set into the angle between the sill of the window and the rail of the panel back, and thus finishes the joint. The stiles of the panel back are considerably wider than shown at (*a*), as they extend beyond and behind the jamb lining.

60. Sashes.—In construction, **sashes** vary slightly, according to the manner in which they are hung and the character of the building for which they are intended. Sashes of ordinary dimensions are from $1\frac{3}{8}$ to $1\frac{7}{8}$ inches in thickness, with the bottom rail $3\frac{1}{2}$ to 4 inches in width, while the stiles and top rail are 2 inches in width. The meeting rails of double-hung sashes are usually $1\frac{3}{8}$ inches wide, and are beveled, as hereafter described, to insure a tight joint.

Sashes that are to be glazed with heavy plate glass should be at least 2 inches thick, and should have a bottom rail 4 or 5 inches wide.

The outside dimensions of window sashes depend largely on the regular market sizes of glass, it being economical to use glass in sizes that can be procured without cutting to waste.

61. Water-Tight Sash.—Unless properly constructed and kept thoroughly well painted, the edge of the lower sash of all windows suffers from the action of capillarity. Where a film of water is allowed to form between the sill of the window frame and sash, as shown in Fig. 29, it readily follows the vertical grain of the stiles, while the action of the wind will keep packing the rain drops until the inner sill is also made wet. This may be prevented by forming a groove on the sill of the window frame and also on the lower edge of the sash, as shown in Fig. 30.

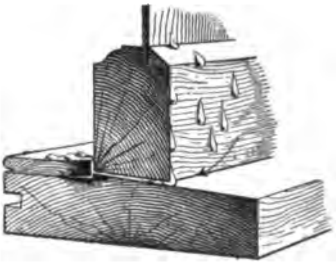


FIG. 29

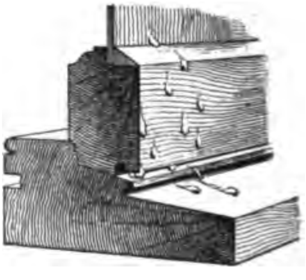


FIG. 30

62. Triple Windows.—Considerable difficulty is sometimes experienced in providing a means for controlling the movable sashes of a **triple window** having two stationary side sashes, a double-hung center window, and mullions as narrow, for instance, as 2¼ inches, as shown in Fig. 31. There are several ways of overcoming this difficulty, however. The easiest method is to use spring sash balances, the mortises for which should not be deep enough to cut through the mullions. But as these appliances are rather expensive and not always satisfactory, the sashes may be hung with pulleys and weights, as shown in the figure. In (*a*) is shown an outside view of the upper part of such a window, while in (*b*) is shown the working system, which needs no explanation. Clean, neat holes for the sash cords should be bored into the yoke, and ordinary pulleys, over

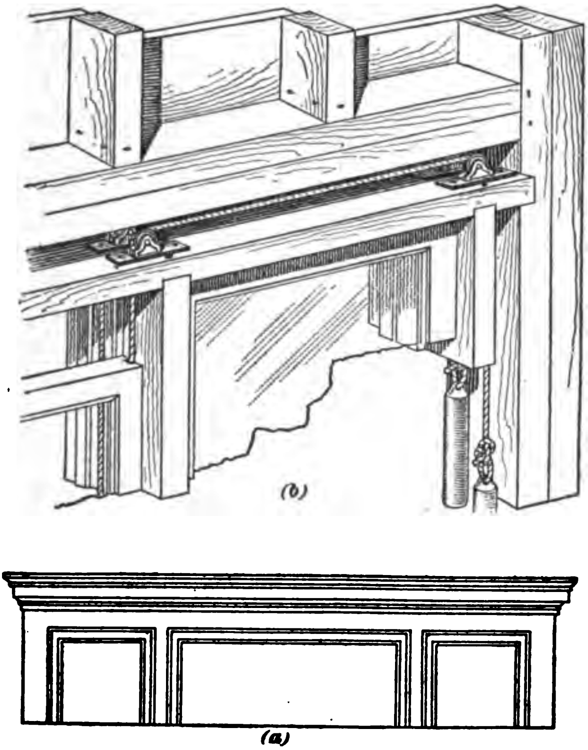


Fig. 31

which the cords pass to the weight boxes at the sides of the entire frame, are screwed face downwards over them. A wider space than usual, say 2¼ inches, should be left between the yoke and the framing; and the inside architrave over this pocket should be fastened with screws, so that the pulleys can be reached in case they get out of order.

63. Window Glass.—In Table I are given the sizes of window glass and the number of panes in a box. While many other sizes are made, those given in the table are carried in stock by the average hardware merchant. A box is supposed to contain 50 square feet of glass.

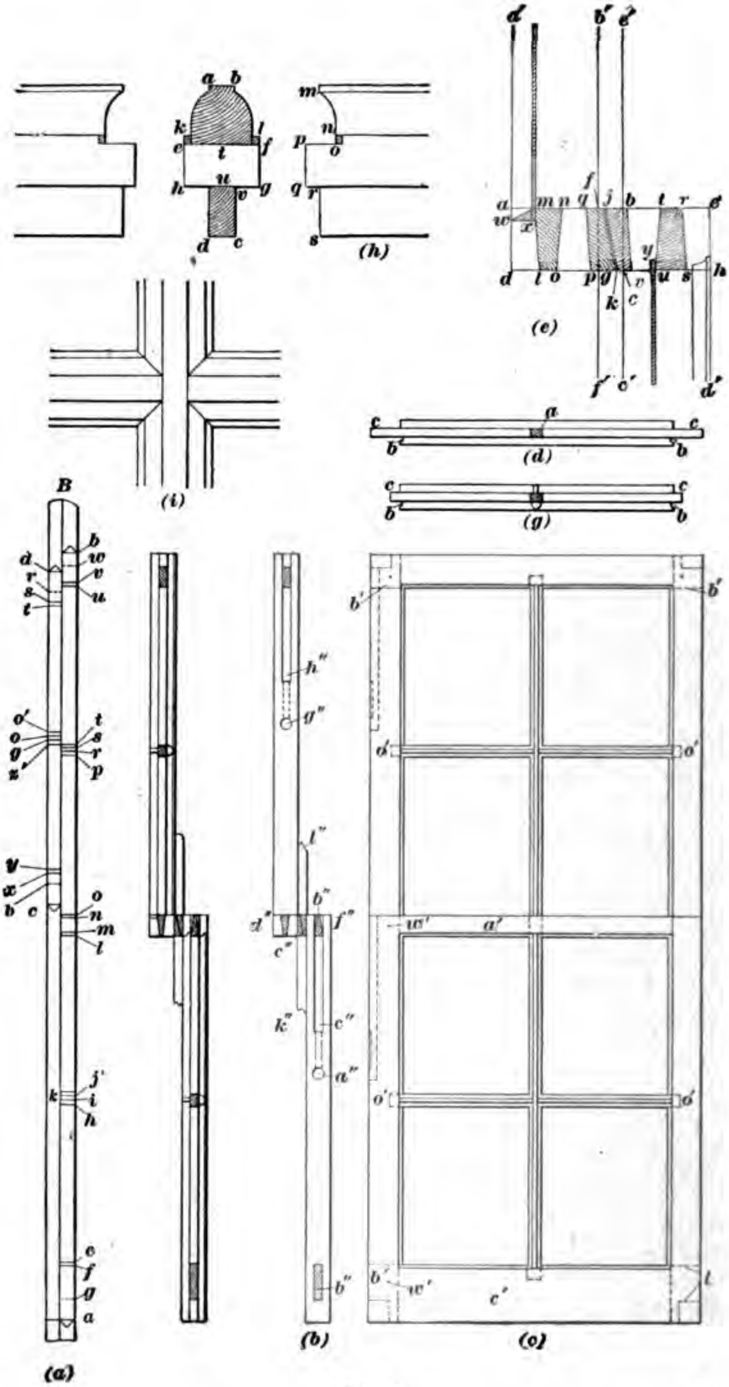
64. Large plate-glass windows are usually designed to have the sash pivoted at the center of the top and bottom rails, if the sash is for one pane, and is too heavy to balance with weights; or, if a muntin or pair of meeting stiles down the center is not an objectionable feature, the sash may be of the form known as the *French casements*, where the two sashes are hinged to the frame and meet and lock together in the middle like a pair of folding doors.

65. Sash Making.—Like all framed work in joinery, **sash making** is preceded by the preparation of a measuring rod, on which are laid out the various dimensions. Fig. 32 shows a pair of sashes for a double-hung window, the lights of which are to be 8 in. × 10 in. A rod of proper length, as shown at (*a*), is first prepared as follows: On one side of the central dividing line is laid off the distance *ae*, equal to the width of the bottom rail, which in this case is 3½ inches. From *e* to *f* is laid off $\frac{3}{16}$ inch for the rabbet, and from *f* to *i* is measured 10$\frac{1}{16}$ inches for glass; *ih* is then laid off $\frac{3}{16}$ inch for rabbet, and *ij* is laid off ½ inch for the tongue of the astragal; *kj* is then made $\frac{3}{16}$ inch for rabbet, and *jm* is laid off 10$\frac{1}{16}$ inches for glass. The $\frac{3}{16}$-inch rabbet is again laid off from *m* to *l*, and *lo* is made 1½ inches for the meeting rail. The upper sash is then laid out in the same way—a rabbet of $\frac{3}{16}$ inch at *on*, an opening for glass of 10$\frac{1}{16}$ inches at *nr*, another $\frac{3}{16}$-inch rabbet *rp*, a ½-inch tongue *rs*, a rabbet *ts*, a light *sv*, and a top rabbet *vu*; *ub* is then made

TABLE I

SIZES AND NUMBER OF PANES IN A BOX OF WINDOW GLASS

Size Inches	Panes in Box	Size Inches	Panes in Box	Size Inches	Panes in Box	Size Inches	Panes in Box
6 × 8	150	12 × 26	23	16 × 20	23	24 × 40	8
7 × 9	115	12 × 28	22	16 × 22	21	24 × 44	7
8 × 10	90	12 × 30	20	16 × 24	19	24 × 50	6
8 × 12	75	13 × 15	37	16 × 26	17	24 × 56	5
8 × 14	64	13 × 16	35	16 × 30	15	26 × 36	8
8 × 16	56	13 × 18	31	16 × 36	13	26 × 40	7
9 × 11	73	13 × 20	28	16 × 40	11	26 × 48	6
9 × 12	67	13 × 22	25	18 × 20	20	26 × 54	5
9 × 13	62	13 × 24	23	18 × 22	18	28 × 34	8
9 × 14	57	13 × 26	21	18 × 24	17	28 × 40	7
9 × 16	50	13 × 28	20	18 × 26	16	28 × 46	6
9 × 18	45	14 × 15	34	18 × 34	12	28 × 50	5
9 × 20	40	14 × 16	32	18 × 36	11	30 × 40	6
9 × 22	36	14 × 18	29	18 × 40	10	30 × 44	6
10 × 12	60	14 × 20	26	18 × 44	9	30 × 48	5
10 × 14	52	14 × 22	24	20 × 22	16	30 × 54	4
10 × 16	45	14 × 24	22	20 × 24	15	32 × 42	6
10 × 18	40	14 × 26	20	20 × 26	14	32 × 44	5
10 × 20	36	14 × 28	18	20 × 28	13	32 × 46	5
10 × 22	33	14 × 30	17	20 × 30	12	32 × 48	5
10 × 24	30	14 × 32	16	20 × 34	11	32 × 50	5
11 × 12	55	14 × 34	15	20 × 36	10	32 × 54	4
11 × 14	47	14 × 36	14	20 × 40	9	32 × 60	4
11 × 16	41	14 × 40	13	20 × 44	8	34 × 40	6
11 × 18	37	15 × 16	30	20 × 50	7	34 × 44	5
11 × 20	33	15 × 18	27	22 × 24	14	34 × 46	5
11 × 22	30	15 × 20	24	22 × 26	13	34 × 50	4
11 × 18	36	15 × 22	22	22 × 28	12	34 × 52	4
12 × 12	50	15 × 24	20	22 × 36	9	34 × 56	4
12 × 14	43	15 × 26	19	22 × 40	8	36 × 44	5
12 × 16	38	15 × 28	17	22 × 50	7	36 × 50	4
12 × 18	34	15 × 30	16	24 × 28	11	36 × 56	4
12 × 20	30	15 × 34	14	24 × 30	10	36 × 60	3
12 × 22	27	16 × 16	28	24 × 32	10	36 × 64	3
12 × 24	25	16 × 18	25	24 × 36	9	40 × 60	3



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c'
h''
g''
l''
b''
d''
f''
c''
k''
e''
a''

FIG. 32

2 inches for the width of the top rail. The top and bottom rails are tenoned into the stiles, and *a g* and *b w* are laid out on the rod for a relish.

On the other side of the bar, from *c* to *d*, the divisions of the width are laid off in the same manner; *d t* and *c y* are each made 2 inches for the width of the stiles, *t s* and *y x* are then laid off for rabbet, and *t r* and *y b* are each made ½ inch for the length of the tenon on the astragals; *s o* and *x g* are then made 8$\frac{1}{16}$ inches for glass, and the tongue *o g* is made ½ inch.

66. In Fig. 32 (*b*) is shown the side elevation, and in (*c*) the interior elevation of the two sashes in their relative positions. The upper and lower rails *a'* and *c'* are tenoned into a mortise in each stile, as shown dotted at *b'*, and are secured by means of $\frac{5}{16}$-inch pins *w'*. The tenons extend all the way through the stiles, and may be seen on the side of the sash shown at *b''*. The astragals are also tenoned into a mortise sunk into each stile, but extend only ½ inch into the wood, as shown at *d'*. The meeting rails are dovetailed to the stiles, as shown at *f'' d'''* in the side elevation (*b*), and the vertical astragals are mortised into the top and bottom rails, and are themselves mortised to receive the tenons of the cross-bars, as described later.

In Fig. 32 (*d*) is shown the top edge of the lower rail, in the center of which is sunk the mortise *a* for the astragal; on the ends are shown the tenons *c*, which are to fit the mortises in the stiles. The molding on the inside of the rail is not mitered in the angle, but is coped over the stile molding, as shown at *b* and described hereafter.

67. In Fig. 32 (*e*) is shown a section through the meeting rails, which illustrates the method of cutting the dovetails on the stiles to insure a satisfactory joint. The two meeting rails are first planed down to a section of 1¼ in. × 2¼ in. This would cause them to occupy the positions shown at *a b c d* and *e f g h*, but they are afterwards beveled off on the line *j k*, as explained hereafter. The lower ends of the stiles of the upper sash and the upper ends of the stiles of the lower sash are then dovetailed, as shown at *adlm* and *nopq* and at *sreh* and *vbtu*; the dovetail pins *lmno* and *utrs* are then cut on the meeting rails, and insure a joint that will be unlikely to work loose or shrink out of place after the sashes are hung. On the outside of the lower rail of the upper sash, a rabbet *wxm* is cut to receive the glass; and on the under side of the upper rail of the lower sash, a groove *uy* is plowed to receive the upper edge of the glass in this lower sash.

The thickness of the stiles of the sash is only 1¾ inches from a' to b' or from c' to d', while, as stated before, the meeting rail extends nearly ½ inch beyond this, or close to the edge of the parting strip. When the sashes are hung, the edge of each meeting rail is planed off to the line *jk*. Thus, when the sashes are closed in the position shown in the illustration, the beveled edges will act as a wedge, and by insuring a tight joint will tend to prevent the sashes from rattling.

68. In Fig. 32 (*g*) is shown a plan of one of the horizontal bars mortised into a vertical one, thus dividing the sash into four parts. At *c* is shown the projection of the tenon that enters the mortise in the side of the sash, while the molding on the sash bar is cut out to cope over the molding on the stile, as shown at *b*. The vertical bar is also similarly coped and mortised into the top and bottom rails of each sash, while at its center a mortise is cut through the stuff to receive the tenons on the middle ends of the horizontal sash bars.

This is more clearly shown in (*h*), where *abcd* is a section through the vertical bar at the center of the joint. At *efgh* is shown the portion that is cut through to receive the tenons of the sash bar, and at *ek* and *fl* are shown the mitered edges of the upper portion of the square section of the bar. These parts are so joined as to present a neat appearance, as well as to insure a perfect joint. The upper part of the bar *mn* is cut out to cope over the molded part of the bar at *bl*, and the tenon *opqr* is inserted in the mortise *efgh* but extends only half way through it, or to the center line tu, leaving the other half of the mortise $etuh$ for the tenon on the other half of the horizontal bar.

The portion rs then butts against the rib at vc, and the whole is secured in place by the pressure of the stiles of the sash against the outer ends of the horizontal bars.

Mortising the horizontal bars into the stiles is effected in precisely the same manner as mortising into the vertical bar, the molded portion being coped and the solid central part let into the mortise.

69. At a'' in the side elevation, Fig. 32 (b), is shown a round hole $\frac{7}{8}$ inch in diameter and $\frac{3}{4}$ inch deep. A hole like this is bored into the sides of each sash just above the middle, so as to receive the knot of the sash cord that is to extend over the pulleys to the balance weights in the weight box. A groove $\frac{1}{2}$ inch wide and $\frac{1}{2}$ inch deep at $c''b''$ and extending from the top of the sash to c'' is cut for the cord to lie in; and a hole $\frac{3}{8}$ inch in diameter, bored from c'' to the $\frac{7}{8}$-inch hole at a'', as shown by the dotted lines $c''a''$, holds the cord in place and prevents the knot from slipping out of the hole at a''.

At $k''l''$ in this side elevation (b) is shown a portion of the parting bead in its position relative to the sashes. It will be readily seen that, as the meeting rails of the sashes extend beyond the interior and exterior faces of the upper and lower sashes, respectively, the beveled portion of these rails must be notched out on the ends to fit around the parting bead.

70. When all the parts of a sash are made—stiles, rails, vertical and horizontal bars—the whole frame is drawn together with bench clamps, and wedges dipped in glue are driven in on each side of the tenons b', Fig. 32 (c). The mortises are made $\frac{1}{2}$ inch wider on the outside than on the inside of the stiles, to make room for the wedges, which are driven until the joint is closed tight. Holes $\frac{1}{4}$ inch in diameter are now bored through each mortise and tenon b' and each dovetail joint, and wooden dowels dipped in glue are driven through the joint to secure it, as shown at *w'*. Barbed steel or iron pegs are often used instead of wooden dowels. When the clamps are removed, the faces are smoothed and made ready for fitting into the frames.

71. Glazing.—Sashes should always receive one coat of paint before they are glazed. This is done in order to prevent the wood from absorbing the oil from the putty with which the glass is fixed in place, and thereby rendering the putty brittle and inadhesive.

In glazing the sash, the rabbet is first prepared by spreading a thin layer of putty along the glass bearing. This forms a cushion against which the panes of glass rest, and they are partly secured by means of small triangular pieces of zinc or tin, called *glazing brads*, which are driven into the wood against the face of the glass. Putty is then spread in the rabbet, to form a triangular fillet and permanently hold the glass in place. This putty extends to the outside of the rabbet and up the face of the glass to within $\frac{1}{16}$ inch of the daylight opening. The back putty that has squeezed out between the pane and the glass bearing is then scraped off flush with the daylight opening, and the sash is set aside to await its second coat of paint.

If a pane of glass is curved slightly, it should be placed with its convex face to the weather, and, if warped so that its surface is not even, it should not be forced to a full bearing in the rabbet, but should be permitted to lie naturally in place. Any unevenness should be taken up in the bearings by *back puttying*—that is, the space between the glass and the bearing face of the rabbet is filled with a thin layer of putty, against which the uneven surface of the glass may rest.

72. Fitting and Hanging Sash.—To fit and hang the sash in the window frame, it is first necessary to remove the stop-bead and parting strip and then fit the upper sash so that it slides easily between the pulley stiles. The parting strip is then replaced, and the sash is secured in place by nailing a couple of wooden blocks under it. The lower sash is then similarly fitted. The lower rail of the sash is then planed off until the meeting rails rest snugly together, as required.

In providing weights for the sashes, the pair for the upper sash must be at least half a pound heavier than the weight of the sash, while for the lower sash the weights must be at least half a pound less than the weight of the sash. This half-pound excess in the upper weights and in the lower sash tends to keep the sashes close and tight against the window head and the sill.

To hang the sash, the pockets must be opened by unscrewing and removing the covers. The sash cords are carried over the pulleys by means of a piece of light but strong string. Previous to inserting the cords this light string is forced over the pulley and drawn down within the box by means of a lead weight, called a *mouse*, which is small enough to go over the pulley sheave, and also heavy enough to carry the string. The sash cord is then made fast to the weight, and, with the top sash resting equally on the sill, the weight is pulled up to the pulley, and the cord is cut off just long enough to permit a knot to be tied at the required point. When both weights for the upper sash are thus attached, the sash is removed from the frame far enough to permit the cord to be pushed down through the groove and the hole shown at $g'' h''$, Fig. 32 (*b*), and a knot is tied to prevent it from pulling out. By the use of metallic-cord grips, knots on the ends of the sash cord are not required, but care should be taken to have the grip of a size to properly fit the cord. When both weights and both cords are thus attached, the sash is replaced in the frame and pushed up and down a few times to test its efficiency. The lower sash is then hung in a similar manner. When both sashes are hung and are found to slide satisfactorily, the stop-bead is replaced and secured, and the pocket is closed and screwed up tight, to prevent the cover from catching on the lower sash.

73. French Windows.—As previously mentioned, hinged sashes are divided into two general classes; namely, those hinged at the sides, and those hinged at the top or

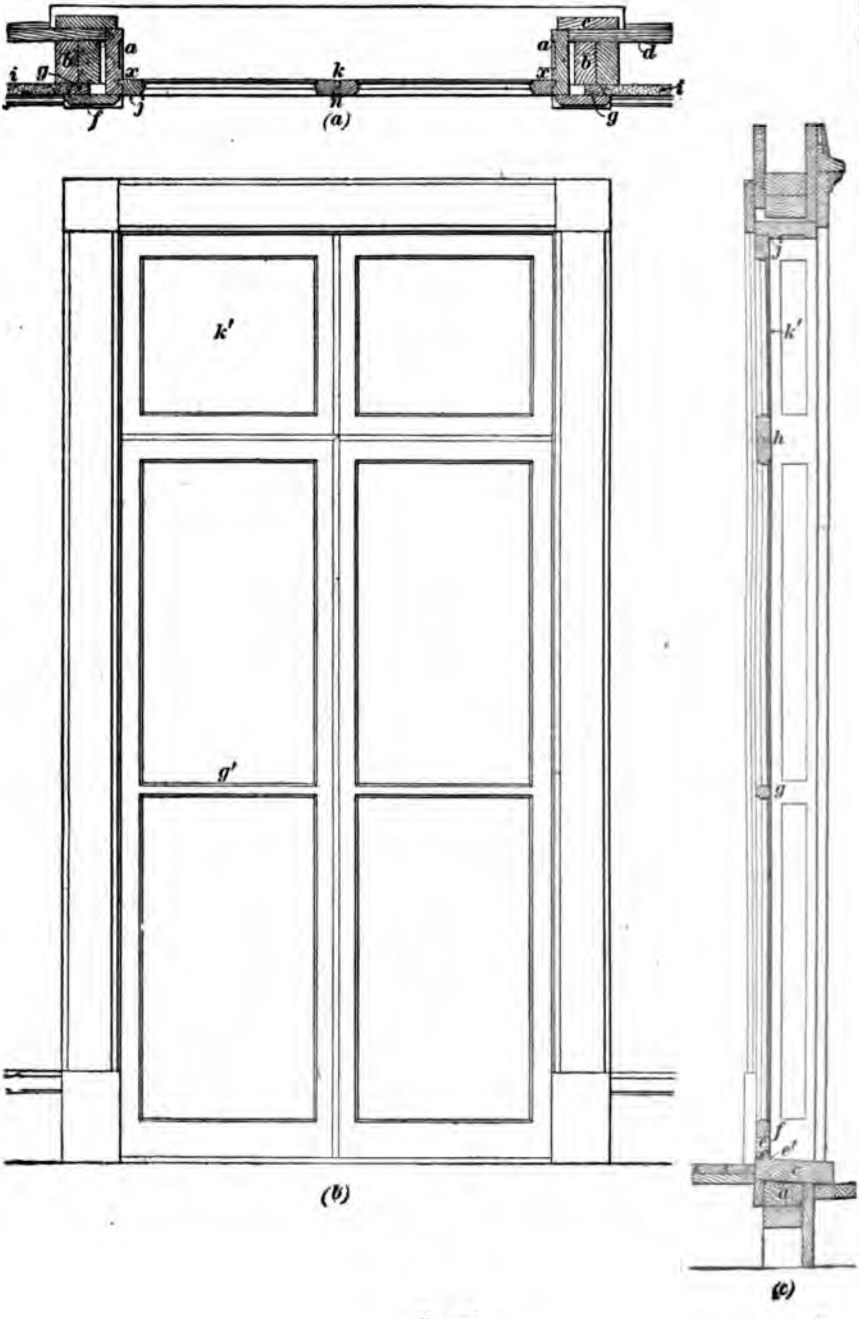

FIG. 33

bottom. The first named are usually hung in pairs, closing at the center with rabbeted meeting stiles in much the same way as a pair of folding doors, and are called **French casements**, from the country of their origin.

Fig. 33 shows the plan (*a*), elevation (*b*), and section (*c*) of a French window, together with the general details of its construction. In the plan (*a*) are shown the double studs *b* forming the sides of the frame opening, over which the sheathing *d* is laid on the outside, and the grounds *g* and lath and plaster *i* on the inside. Extending through the opening, from the sheathing to the grounds, are the jambs *a*, the joints of which are covered on the outside by the casing, or blind-hanging stile, *c*, and on the inside by the trim *f*. Between these jambs, the two sashes are hinged and tongued into the jambs, as shown at *x*; the corners of the stiles, however, are rounded, as shown, to permit them to clear the groove in opening. The sashes are hung with small hinges, and the meeting stiles are rabbeted in the same manner as are folding doors, as shown at *k n*, to enable them to make a tight joint when closed.

In the vertical section (*c*) taken through the center of one of these sashes, the rough sill of the stud opening is shown at *a*, while the window sill resting on the veranda floor is shown at *c*. This sill covers the bottom of the opening from the veranda floor to the inside of the lower sash rail *f*. This sash rail is grooved on its under side, as shown at *e*, and the sill is worked with a shoulder, the front of which is also grooved, as shown at *e'*, while the top of it is beveled off at the same pitch as the sill. The groove in the front of the shoulder *e'* tends to prevent water from being blown into the crack during a rainstorm, and the slanting sill and the grooved lower rail permit the moisture to drip off the latter and run to the outside of the opening.

At *g* is shown the section of the middle bar of the window, which may also be seen in the elevation at *g'*, and at *h* is shown the top rail of the hinged sash and the lower rail of the fixed transom sash *k'* over it. The hinged sash is only 5 feet 6 inches in height, as this is sufficient to permit the window to be used as a means of ingress and egress, while the full opening is 7 feet high.

In the construction of the window head, the framing is precisely the same as at the sides, shown in the plan (*a*), except that the jamb *j* in the top of the window is not grooved as at *x* in the plan (*a*).

JOINERY

(PART 2)

GENERAL JOINERY—(Continued)

WINDOW DESIGN AND CONSTRUCTION
(Continued)

1. Windows in Curved Walls.—When the wall in which a window frame is to be built is not straight, as described in *Joinery*, Part 1, but curved, as would be the case in a circular tower or a semicircular bay window, it is necessary to make a special form of frame laid out from a templet of the exact curve it is required to fit. Also, if, in addition to the wall being curved, the head of the window is semicircular or semielliptical, the problem is still further complicated by the necessary geometrical development of the details.

In Fig. 1 is shown the plan of a window opening and its frame built in the curved wall of a tower. The pulley stiles *a*, *a* are set parallel with the axial line *n f* of the opening, so that the sash may be easily removed and replaced from the inside of the structure, which could not be done if the stiles were set on radial lines from the center of the curve.

The back lining is set parallel with the pulley stile to form a proper weight box, and the other details of construction are precisely similar to those described in connection with windows in straight walls, except that, owing to the curvature of the sill and head, the details of the framing do not join at right angles and the semicircular shape of the window head demands special construction.

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2. To unfold, or develop, this semicircular window head, proceed as follows: Draw a line $a\,a$ from the inside edges of the pulley stiles, and from each end of it erect the perpendiculars a, b, which will be equivalent to the continuation of the inside faces of the pulley stiles. Above the plan, draw the line $b\,b$ parallel with $a\,a$, and with the point where this line intersects the axial line $n\,f$ at d as a center, and $d\,b$ as a radius, draw the semicircle $b\,f\,b$, which will be the elevation of the inside line of the window head. Now, divide one-half of this semicircle $b\,f\,b$ into any number of equal parts by points u, v, w, x, etc., and from these points let fall perpendiculars to $a\,a$, as shown at $x\,l, w\,j, v\,h$, etc.

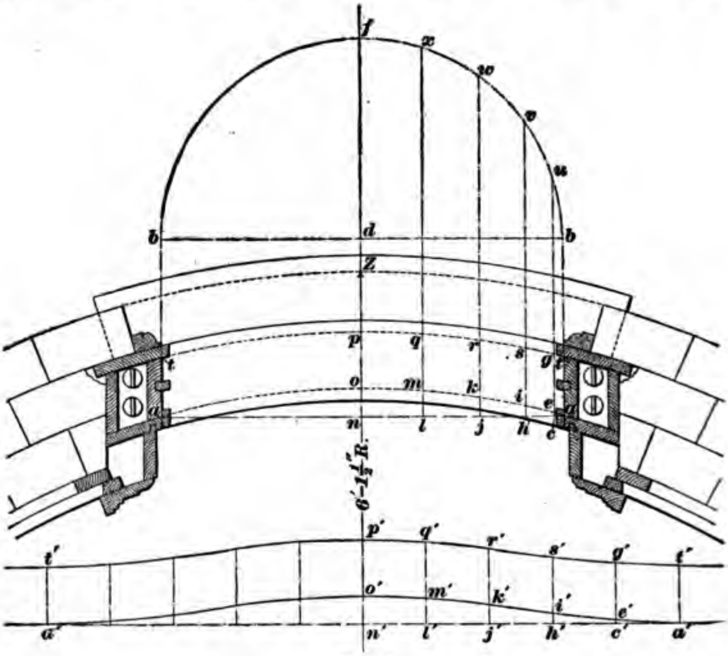


FIG. 1

Somewhere below the plan, the line $a'\,a'$ is then drawn parallel with $a\,a$. From the center n' of the line $a'\,a'$ are laid off in each direction the lengths $n'\,l', l'\,j', j'\,h'$, etc., each equal to the length of the curved lines $f\,x, x\,w, w\,v$, etc., and, from the points so established, perpendiculars to $a'a'$, as $n'p'$, $l'q'$, $j'r'$, $h's'$, etc., are erected. On these perpendiculars are laid off $n'o'$ and $n'p'$ equal, respectively, to no and np, $l'm'$ and $l'q'$ equal to lm and lq, $j'k'$ and $j'r'$ equal to jk and jr, etc. These measurements are taken from the plan, where the perpendiculars from the subdivisions of the semicircle bfb intersect the curved lines aoa and tpt, shown in the plan of the sill. Curved lines drawn through the points p', q', r', s', g', t' and o', m', k', i', e', a' will describe the contour of the flat piece required to conform to the shape of the window head when bent around a semicircular form similar to bfb. The method of bending this semicircular head is described in subsequent articles.

3. The construction of a sash whose plan is the segment of a circle, and whose head is a semicircle, is shown in Fig. 2; it is designed to fit the curved window frame just described.

The most satisfactory way of constructing this sash head is to form it of two pieces, each piece being a quarter circle; and, as each of these quarter circles will have a compound curve, it will be necessary to prepare a face mold from which to mark out the curve. To do this, first draw the line ab, Fig. 2, on the concave side of the sash, from the outside edge to the center, and on the convex side draw the line cd parallel with ab and tangent to the sash at u; also, draw ac perpendicular to ab. The rectangle $ab''dc$ then represents the thickness and width of plank required to get out each piece of the top rail. Now, divide the curved outside line of the elevation of one-half the window head $a'b'$ into any number of equal parts by points g', and from each of these points draw lines parallel with the center line $b'e$, intersecting ab at r, t, etc.; and from these points of intersection draw the lines bg, rj, tl, etc., and the line df, all perpendicular to ab. Lay off on these lines the distances bd', bg, rm, rj, tm', tl, etc., equal, respectively, to $o'c'$, $o'b'$, $e'f'$, $e'g'$, etc., and through the points thus established draw the curves alf and $nm'd'$. Then, the curved form $algd'm'n$ will be the face mold that must be applied to and scribed on the stock from which the half-sash head is to be sawed. The shaded portion at *gf* shows the waste, or surplus, that must be removed in order to permit the two quadrants to meet in a proper butt joint at *be*. This surplus is removed on the

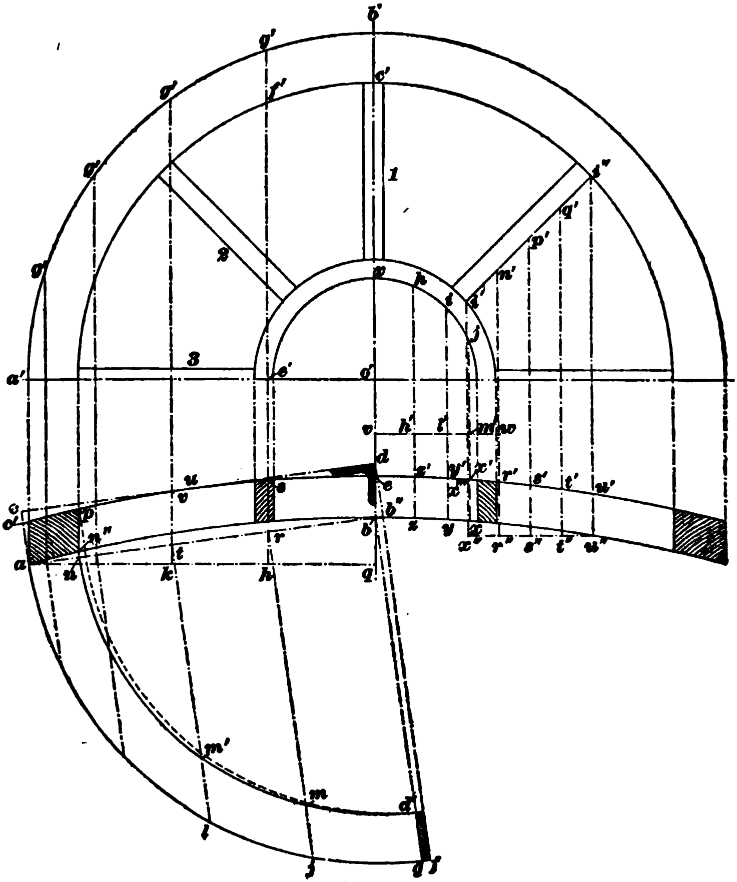


FIG. 2

bevel shown at *d*, which is the angle *cdq* formed by the intersection of the tangent line *cd* with the prolongation of the perpendicular center line *b' b*.

The dotted curved line on the concave side of the face mold shows the amount of extra width required, owing to the fact that the head-piece is sawed squarely through the wood. The plank from which the sash head is to be cut is first planed on its inside edge, to conform with the bevel shown at d. The face mold is then set to the edge of this bevel on both sides of the plank and marked, and the surplus wood is then cut away to the lines, as marked. The convex and concave edges of the circular head on the plan lines $a c' e b$ and $n'' p e b$ will then have the proper shape and angle. The dotted line on the concave edge shows the relative position of the curves $n'' d'$ and $p d'$ on the inside and outside of the sash in the projected elevation. A perpendicular line drawn from p gives the amount of the warp or twist.

4. It now becomes necessary to make two patterns that may be applied to the finished convex and concave edges of the circular top rail, in order to mark the convex face line of the sash. To prepare these patterns, first draw a line $a b$, Fig. 3; on it lay off the distances $a d$, $d g$, etc. equal to the divisions $a' g'$, $g' g'$, etc. on the convex side of the sash head $a' b'$, Fig. 2, and from these points erect the perpendiculars $a c$, $d f$, $g i$, etc., equal, respectively, to $q e$, $h s$, $k v$, etc., Fig. 2. Then, through the points c, f, i, etc., Fig. 3, draw a curved line, which will be the line required on the convex face of the sash head. Before applying this pattern to the sash head, it will be necessary to trace another curve $l e h b$, which will act as a guide in placing the pattern in position for scribing. To do this, $a l$, $d e$, $g h$, etc. are laid off equal to $q b$, $h r$, $k t$, etc., Fig. 2, and the curve $b h e l$, Fig. 3, is then drawn through the points so located. The pattern $b h l c i k$ is then cut out, and is bent around the convex edge of the rough-sawed window head $a b d c$, Fig. 2, in such a position that $b h e l$ corresponds with the inside line of the plank, as

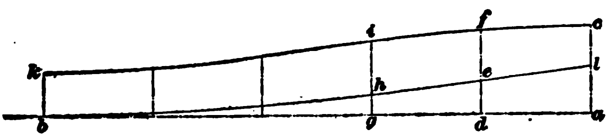


FIG. 3

atrb of Fig. 2. The outside curve *kifc* is then scribed on the sash head, and will conform to the curve required.

The other pattern must trace this same curve on the concave side of the sash head. On the line *wk*, Fig. 4, are laid off the distances *ko*, *or*, etc. equal to *c′f′*, etc., on the concave side of the window head in Fig. 2, and, on the perpendicular lines raised from these points, the distances *km*, *kn*, *op*, *oq*, *rs*, *rt*, etc. are laid off equal, respectively, to *qb*, *qe*, *hr*, *hs*, *kt*, *kv*, etc., Fig. 2. The curves traced through the points *nqtx* and *mpsw*, Fig. 4, will then form the pattern for the concave side of the window frame. This pattern must be applied in the same manner as the pattern described in Fig. 3 is applied to the outside, the line *mpsw* being made to conform to the straight line *nb* of the concave side of the sash shown in Fig. 2.

These patterns may be cut out of either strawboard or thin sheet zinc, so that they may be readily bent to the curved edges of the top rail. The pattern shown in Fig. 3 is bent around the outside of the top rail, pressed closely, and temporarily tacked into place, keeping *lc* to the joint and the line *lehb* to the straight face of the plank marked *ab* on the plan in Fig. 2, the convex face line *cfik* being then marked on the sash head. The pattern shown in Fig. 4 is applied in the same manner to the under, or concave, side of the sash head, keeping the line *mn* to the joint and scribing the curve *ntx* on the outside, or front, edge of the sash. The surplus, or overwood, is then planed off to the convex lines so marked on the sash head, always working the plane in a direction parallel with the joint line *gd′*, Fig. 2. When this is done and the convex face of the frame is finished, the scratch gauge is set to the thickness of the sash, and the concave, or inner, face of the sash is gauged

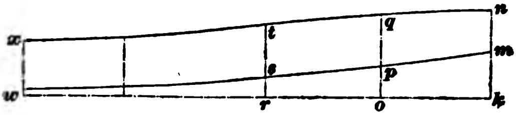


FIG. 4

from the outside. The overwood is then removed as before, moving the plane in the same direction and finishing carefully to the scribed lines.

The two quadrants, each representing one-half the sash head, are now doweled together, as shown at *b* and *b'*, Fig. 5, and secured with a hand-rail bolt in the center, as shown at *a* and *a'*, to bring them into close contact, while a dowel in each of the two opposite corners at *b'* serves to keep the pieces in proper alinement. The pieces are then glued together, and the moldings are worked.

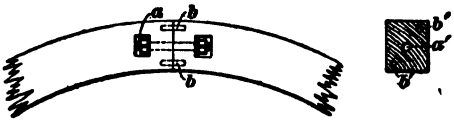


FIG. 5

5. The arch bar may be sawed out of a single piece of plank in the same manner as each half of the window head, or it may be bent in one or more thicknesses of wood, laid out from a pattern drawn as follows: The concave side of the arch bar, Fig. 2, is divided into a number of equal parts by points *h*, *i*, *j*, etc., from which perpendiculars are dropped to the plan, intersecting it at *z'*, *z*; *y'*, *y*; *x'*, *x*; etc. At any convenient point above the plan, a horizontal line *v w* is drawn, intersecting the perpendiculars at *h'*, *l'*, *m'*, etc. Now, on a line *a b*, Fig. 6, the points *v*, *h*, *i*, *j* are laid off on each side of the perpendicular center line *c v* at a distance from each other equal to *v h*, *h i*, *i j*, etc., Fig. 2. From these points, the lines *j x*, *i y*, *h z*, etc. are drawn perpendicular to *a b*, and the distances *j x'*, *j x*, *i y'*, *i y*, *h z'*, *h z*, etc. are laid off on these perpendiculars equal, respectively, to the distances *m' x'*, *m' x*, *l' y'*, *l' y*, *h' z'*, *h' z*, etc., Fig. 2. Through the points *o*, *z'*, *y'*, *x'*, etc. and *c*, *z*, *y*, *x*, etc., curved lines are drawn, giving the proper shape for the front and back edges, respectively, of a plank that is to be bent over a prepared center to form the semicircular arch bar of the sash.

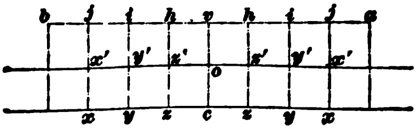


FIG. 6

6. The radial bars in this sash head have different curves, according to their positions. No. *1* is straight, as it is in the center of the convex surface, and is parallel with the axis of the cylinder, of which the curved front of this window forms a part. No. *3* is curved to the arc of a circle, the radius of which is the same as that of the window plan, because it is parallel to the base of the cylinder of which the curved front forms a part. No. *2*, however, being parallel with neither the axis nor the base, takes a diagonal direction around the surface of the cylinder and is therefore curved to the form of a portion of an ellipse.

To lay out the face mold from which this elliptical curve may be marked on the plank for the radial bar, proceed as follows: Divide the length of the radial bar in Fig. 2 into any number of equal parts by the points i', n', p', q', etc., and drop from each division a perpendicular line intersecting the lines on the curved plan at $r'\,r''$, $s'\,s''$, etc. Then, on a horizontal line, as $v'\,u'$, Fig. 7, lay off the distances $v'\,n$, $n\,p$, $p\,q$, etc., equal to $i'\,n'$, $n'\,p'$, $p'\,q'$, etc., Fig. 2, and lay off on the perpendiculars erected at these points the distances $v'\,h$, $n\,r$, $p\,s$, etc., equal to $x''\,x'''$, $r''\,r'$, $s''\,s'$, Fig. 2; then, through the points h, r, s, t, u, draw a curve, which will give the outside line of the face mold required. The inside line of the face mold is then found by drawing a curve through the points h', r', s', etc., which are located so as to make the distances $h\,h'$, $r\,r'$, $s\,s'$, etc. equal to the thickness of the sash on the lines $x'''\,x''$, $r'\,r''$, $s'\,s''$, $t'\,t''$, etc., as shown on plan in Fig. 2.

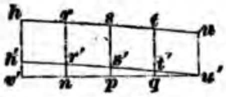


FIG. 7

BEVELS FOR STRINGER CUTS

7. The following is a simple method of finding the bevel cuts for a stair stringer: The bevel is applied to the upper edge of the uncut stringer, so that only one cut is necessary. The cut fits a 45° miter on the riser. On the outside face of the stringer shown in Fig. 8 mark cuts for treads and risers, as $f\,d\,a\,d'\,a'$. Now, parallel with $a\,d$ and at a distance t from *a d* equal to the thickness of the stringer, draw the line *b e*. At point *b*, draw the line *b c* square across the upper edge of the stringer, and connect *c* and *a*. Then, *b a c* is the bevel angle required. At *a′* is shown a bevel applied to the upper edge to mark off the line *a c*, while at *f* is shown the appearance of the miter after cutting. A riser mitered to the stringer is shown at *g*.

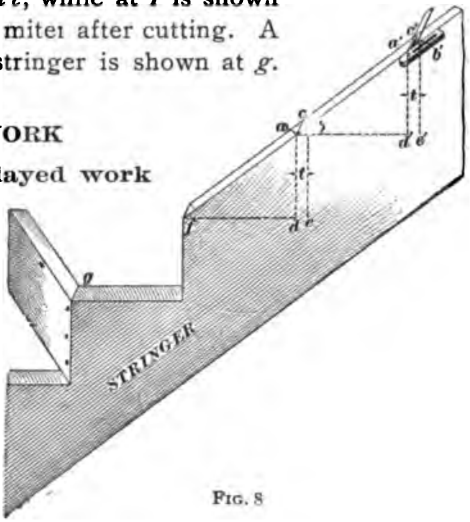


Fig. 8

SPLAYED WORK

8. In joinery, **splayed work** is the term applied to cases in which some of the surfaces slope, or slant, away from or toward other surfaces, such as the sides of a pyramid. Such work is frequently encountered in the jambs, sills, or sides of windows or doors, or in the sides of any piece of work placed in an oblique direction to a horizontal or vertical plane.

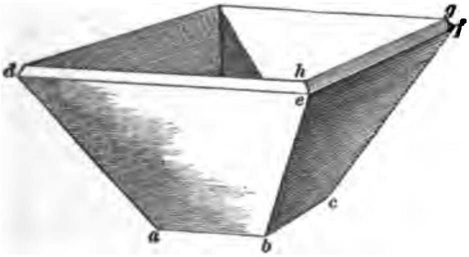


Fig. 9

9. Fig. 9 shows a box, the sides of which *splay* out from the bottom *a b c* to the top *d e f*. To find the angles required in the construction of a square box, or hopper, such as is shown in Fig. 9, all four of whose sides splay equally, proceed as follows: Let *b c*, Fig. 10, be the required splay and position of the sides of a box in relation to the horizontal plane *d s*, and *a b* the thickness of the material from which the box is to be made;

then, *a b c t* is the end section of the material, and *x z b a t y* is a vertical section through the box. From *c*, at right angles to *d s*, draw *c j* equal to *c b*; through *j* parallel with *d s* draw *p h*, and from *b* draw *b h* at right angles to *p h*; connect *h c*; then, the angle *j h c* is the inside face bevel for the sides, and *p h c s* is the size and shape of the inside faces.

10. To find the bevel for a butt joint on the square edge, in Fig. 10, from *a*, draw *a f* parallel with *h j*; from *f*, draw *f g* at right angles to *h j*; make *i g* equal to the thickness *b a*; connect *h g*; then, *j h g* is the bevel.

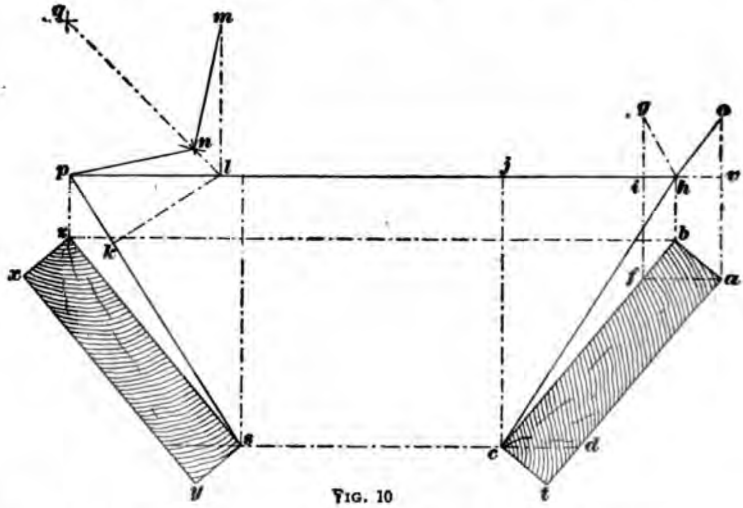


FIG. 10

To find the bevel for a miter joint on the square edge—as *g h e* in Fig. 9—draw *a o*, Fig. 10, perpendicular to *f a*, making *v o* equal to *b a*; connect *h o*; then, *j h o* is the miter bevel.

To find the angle between the two inside faces in a plane at right angles to the face joint *p s*, draw *k l* at any point along the line *p s* and at right angles to it. At right angles to *p l*, draw a line from *l*, and make *l m* equal to *l p*. With *m* and *p* as centers, describe the intersecting arcs at *q*; and connect *q l*; with *l k* as radius and *m* and *p* as centers, describe intersecting arcs at *n*; connect *n* to *m* and to *p*; then, *m n p* is the angle sought. Also, the angle *p n l* is the angle of miter through the thickness, holding the stock of the bevel in the direction *k l*. A block beveled to the angle *m n p* will fit the angle formed by the connecting faces of the box. If

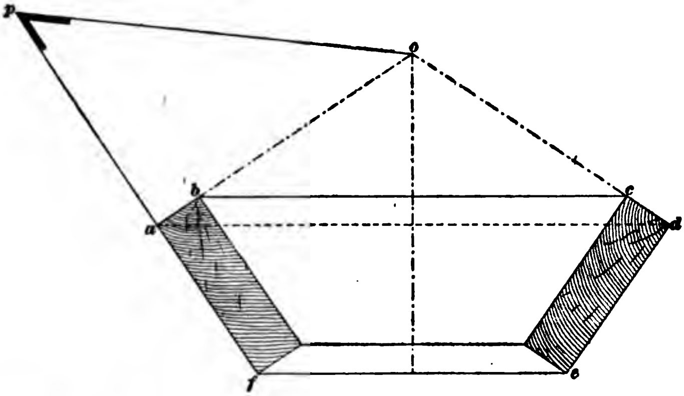
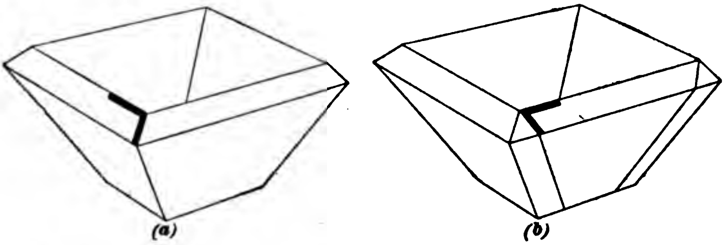


Fig. 11

either edge of the box is cut off horizontally, as at *c d* or *f a*, then a square line on either of these edges from the face *c b* will be a butt-joint line through the thickness. An angle of 45° applied from the outside face on either beveled edge *c d* or *f a* will be a correct miter through the thickness.



(a) (b)

Fig. 12

In dovetailing a box like this, instead of squaring across the ends for mortises, use the angle *c f a* or *d a f*; also, instead of squaring from the ends for the pins, use the angle *c h j*.

A simple method of finding the miter joint on the square edge is shown in Fig. 11. The miter joint is the same as the lower face joint of a pyramid formed by the continuation of the edges *a b* and *d c* until they intersect at the center *o*. Let *a b c d e f* be a vertical section through the center of the box. Lay off *a p* perpendicular to *a o* and equal to half the length of the outside edge *a d*; connect *p o*; then, *a p o* is the required miter bevel to be applied from the outside face.

The application of the miter bevel from the inside edge is shown in Fig. 12 (*a*), and the bevel for the butt joint, in (*b*).

CURVED MITERS

11. To miter a straight and circular molding, the straight molding to be tangent to the circular one: Let *o o′ t t′*, Fig. 13,

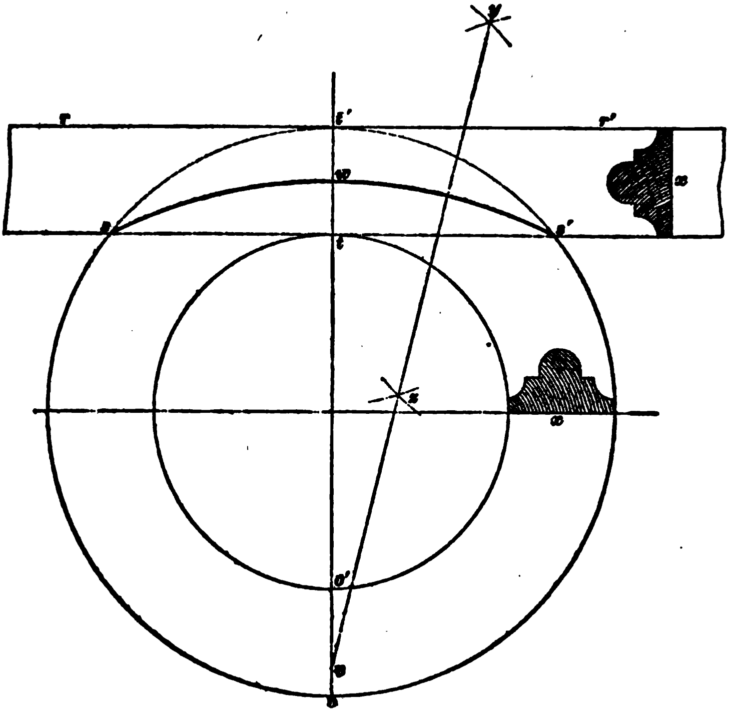


Fig. 13

be the circular molding, and *x* a cross-section of it; let *s s′ r′ r* be a straight molding, with the same cross-section *x*.

Bisect tt' at w; with s' and w as centers and equal radii, describe intersecting arcs at y and z; join y and z, and produce the line to intersect ot' in v. Now, from v as a center, describe the arc sws', which will be the miter line required.

12. To miter a straight and circular molding intersecting at an acute angle: Let $ba'ac$, Fig. 14, be the straight molding, and aa' the cross-section; $zz'cb$ the circular molding, and zz' its cross-section. Through the straight and circular moldings draw the center lines, ts and os, respectively. With c and s as centers and a radius greater than the distance cs, describe intersecting arcs, as r and l, and through r and l draw the line ry of indefinite length. With s and b as centers and a convenient radius, describe intersecting arcs

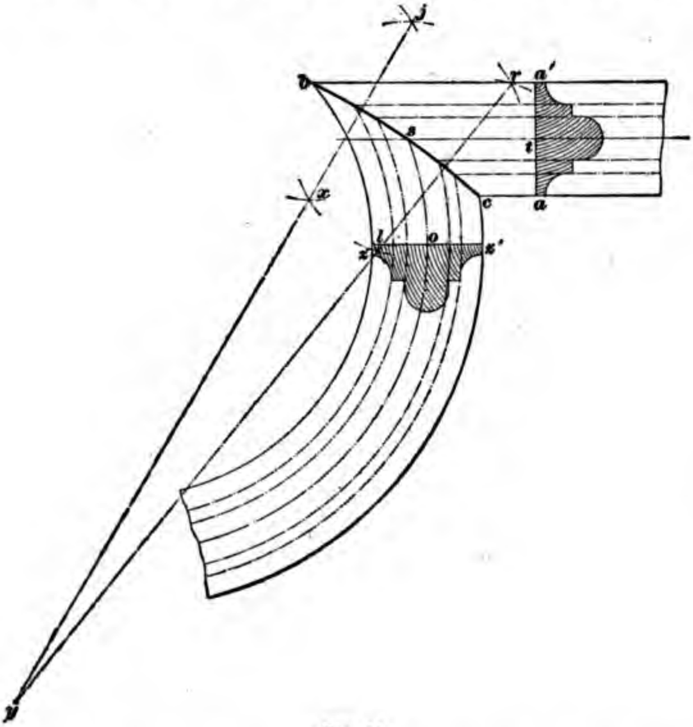


FIG. 14

as *j* and *x*, and through these points draw the line *jy*, cutting the line *rl* in the point *y*. With *y* as a center, describe the curve *bsc*, which will be the miter line required. These miter lines on circular moldings are sometimes called *hunting miters*.

RAKING MOLDINGS

13. The following is a method of finding the profiles of gable moldings to miter accurately with eave moldings: A profile of the eave molding is shown at *abfhjce*, Fig. 15. Let *mdc′* be the pitch angle of the gable molding. To find the profile of a molding that with the given pitch will miter accurately with *abjce*, proceed as follows: Divide *bjc* into any number of parts, as at *f*, *h*, *j*, etc. Through the points of division draw verticals, as *ff′*, etc., and draw *lk* parallel with *dm*. Draw *fg*, etc., parallel with *dc′*, and at any point lay off *k′f″l′* equal to *kf′l*. Draw *l′b′*, etc. perpendicular to the pitch of the gable, cutting *bb″*, *hi*, etc. in the points *b′*, *h′*, etc., which will give points in the required profile.

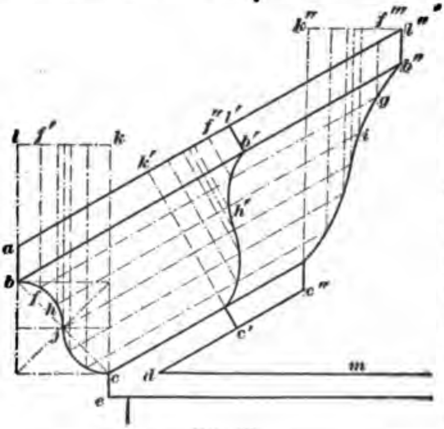


FIG. 15

To find a vertical section of the raking molding, for use in profiling return moldings, at broken pediments, proceed as shown at *b″c″*. Draw *k″l″*, with its divisions equal to and parallel with *kl*. Drop verticals from the points of division as before, intersecting the lines *bb″*, *fg*, etc. in the points *b″*, *g*, *i*, *c″*, etc. By drawing a curve through the points thus found, a vertical section of the return molding is obtained.

BENDING WOOD

14. When a surface must present a curved form, the wood may be bent around it by any one of five methods; namely, by *saw kerfing*, *keying*, *backing a veneer*, *laminating*, or *steaming*.

15. Saw Kerfing.—As **saw kerfing** is less costly than other methods, it is often adopted. The method is not to be recommended, however; it makes a weak construction, and no matter how perfectly the work may be done or how well it may be painted, the saw-kerf marks will always show. For hardwood moldings, the method should never even be considered, and for curved work of any kind, solid molding should always be used.

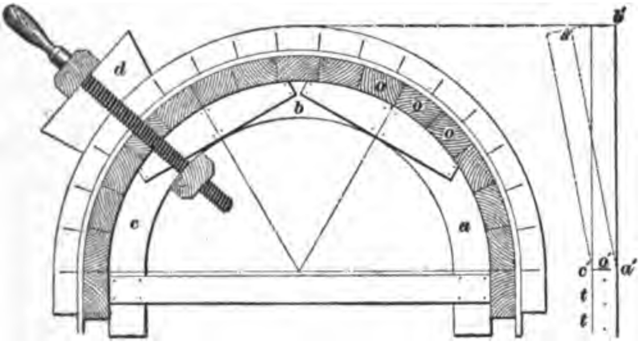


FIG. 16

A center built to the desired diameter, or curve, over which the material may be bent, and which will stay permanently and accurately in its curved form, is absolutely necessary with any of the methods just mentioned. In Fig. 16, the rib *a b c* used for a center is composed of three pieces of 1¼-inch plank. This rib is made concave on its inner edge, merely because it is sometimes an advantage (when it can be done) to clutch the bent stuff and the rib with handscrews, as shown. Blocks, as shown at *d*, extend the power of handscrews considerably beyond the width of the jaws, and are therefore exceedingly useful. The staves of wood *o* of any length required are nailed to the rib *a b c*, and form the circular surface of the center.

To find the distance between saw kerfs that will allow the material to bend to the curve required, take a piece of stuff of a suitable length and equal to the thickness of that which is to be bent, as at *c′ a′*, and let *a′ b′* be equal to the radius of the curve to which it is to be bent. Make a saw kerf at *c′ o′*, leaving a thickness *o′ a′* from $\frac{1}{8}$ to $\frac{1}{4}$ inch uncut; nail the piece at *t*, *t*, and move it from *b′* to *s*, or enough to just close the saw kerf at *c′*; then, *b′ s* will be the given distance between two saw kerfs. The distance *a′ o′* to be uncut must be gauged along each edge of the stuff to be bent, and the same saw must be used with which the cut *c′ o′* was made. In this method of bending, a thin veneer is first laid, and the saw-kerfed piece is then bent over it and glued to the veneer. This is the better method of treatment in saw kerfing, but the saw kerfs may also be cut in the convex face of the stock, and when bent over the center, a veneer may be glued over the convex surface to secure it.

16. Keying.—Fig. 17 shows another method of treating material that must be bent. In this method, known as **keying**, grooves of an even depth, as shown at *a*, are made in the back of the stuff at suitable intervals (found as directed for space between saw kerfs), leaving an interior thickness of $\frac{1}{8}$ or $\frac{1}{4}$ inch, depending on the radius of curvature. These

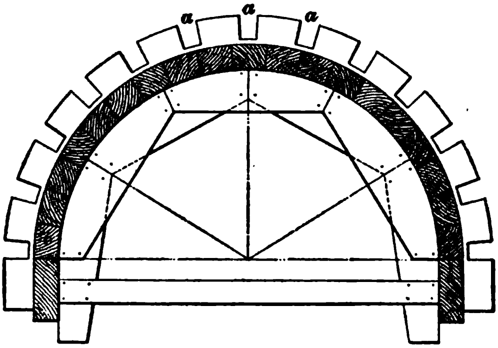


FIG. 17

grooves are filled with well-fitted wooden strips, called *keys*, plenty of glue having first been brushed into the grooves and over the keys. Two strips of veneer from 3 to 4 inches wide are glued and nailed over the convex face of the bent piece near each edge, and thus tend to strengthen the work materially. The ribs of the center shown in Fig. 17 are in four parts, with bracing pieces nailed over each joint as shown.

17. Backing a Veneer.—Bending by **backing a veneer,** the third method, is shown in Fig. 18. Enough wood is planed from the back of the stuff to be bent, to leave a veneer of the proper thickness and length between *r r*, the circumference of the semicircle; then, when bent over the center, the thickness is filled out as required by fitting and gluing cylindrical-faced staves *v* on the back of the veneer. These staves are made a trifle long, and each one after being fitted and glued has a long screw driven through its thickness to the center, near each end, to hold it down and keep it in place until all are fitted and glued. To increase the strength of this curved piece of work, before taking it off the center, the joints may be united by hardwood dowels, glued and driven in as shown at *a*.

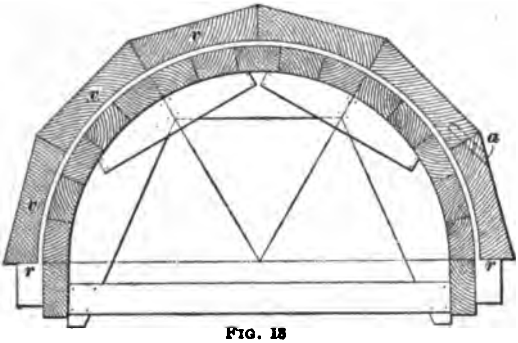


FIG. 18

18. Laminated Curved Work.—The fourth, or **laminating method,** as shown in Fig. 19, is a mode of bending and gluing together several layers, as shown at *a*, to make up the required thickness. These layers should all be fixed and glued over the center at one operation, and, if possible, left there several days to dry out. This is by far the strongest and best method of all for most purposes, but it will not do for moldings, as the hardwood edges when cut into will show the streaks of glue; this, however, would not be objectionable where the work is to be painted.

19. Steaming.—The fifth mode of bending is by **steaming.** Some woods bend easily when steamed, but all must be handled with rapidity after steaming, allowing no time for cooling until after the work is secured to the center. A good steam box of suitable size should be prepared, and wet steam must be used, since dry, superheated steam makes wood brittle but not flexible.

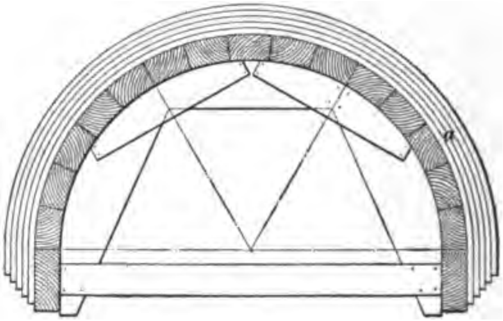


FIG. 19

To find the thickness of white pine (without preparation) that may be bent without injuring its elasticity, multiply the radius in feet of the curvature required by the decimal .05, and the product will be the thickness in inches. For example, take a 5-foot radius; multiplying this by the given decimal, the thickness that will bend without fracture is 5 × .05 = .25, or $\frac{1}{4}$, inch.

VENEERING

20. Hardwoods, such as oak, ash, rosewood, etc., cannot be used in joinery work if the pieces are of any considerable dimensions unless they are backed up with some lighter or more reliable wood that is less affected by moisture or change of temperature. The hardwood, therefore, is usually cut into thin slabs and glued to a piece of pine or other soft wood in such a manner that the finished work has the appearance of a solid block, while in reality its interior, or core, is of an entirely different material. This process is called **veneering**, and the thin slabs of hardwood are called **veneers**. It is a mistake to suppose that veneering is resorted to as a matter of economy, to save the cost of solid wood. Hardwoods are liable to warp or twist out of proper shape; especially is this the case with doors built of solid hardwood. Therefore, in order to make a good door and to secure the decorative elegance in color and grain of the hardwoods, it becomes absolutely necessary to employ veneering in door making. Veneering when properly executed with good glue, will last as long as the wood on which it is laid.

It is not good practice to use two kinds of wood in veneering a door; as, one face mahogany and the other oak; or maple and cherry; oak and black walnut; etc. The varying conditions of heat and moisture act differently on the two kinds of wood, and the doors have a tendency to warp. This is equally the case with a door where one face is in a warm room and the other face is constantly exposed to different atmospheric conditions, even though both sides of the door are veneered alike. If only one side of a panel is veneered, it will curl badly when dry; consequently, both sides should be veneered.

The choicest and most beautiful veneers are cut from the crotches, and, also, with some woods, from the roots of the trees, where the grain is gnarled, mottled, and attractively intermingled. These choice veneers are used on the surfaces of panels, and are highly polished to bring out the beautiful natural changes and color qualities peculiar to the wood; this is relieved by the less-polished plain surface of the framework. The frame, or stiles and rails, is invariably veneered with plain, straight-grained veneers finished flat.

21. There are several valuable accessories to good veneering that must not be overlooked. The first of these is a good heating box of a length and width sufficient for long and short materials. Such a box may be cheaply constructed of plank, and lined with tin, with its cover, or lid, in three sections. The box should be piped and heated by steam; or, in the absence of steam, it may be heated conveniently by a 6-inch stovepipe carried through it lengthwise. In all cases, heated *cauls* are used against veneers to keep the glue hot, so that the wood may the better absorb it. During the several hours required for the glue to set, the caul also distributes the pressure of the handscrews on the whole surface of the veneers evenly. A **caul** is a piece of wood or other suitable material, curved or straight, as the case may be, made to fit the surface to be veneered. When used for door stiles or panels, a thickness of 1 inch will be sufficient for the caul, but its width and length should never be less than that of the material to be veneered. To prevent the caul from sticking to the veneer, it should be coated with beeswax or paraffin; or, in the absence of these substances, brown paper cut to size and laid between the veneer and the caul will serve the purpose. Brown soap is sometimes used, but it frequently stains the wood.

22. In door making, the core should be clear white pine. The stiles are built up of several strips, the grain of each reversed with reference to that of the adjacent piece, and all glued together. The edges of the stiles, shown at (*a*) and (*b*) in Fig. 20, have hardwood strips *h* glued on to form the outer edges. The stile is then faced straight out of wind and is well scratched lengthwise by means of a toothed plane; the veneer should also be scratched. The glue should be well cooked—if burned it is useless—of a good body and not too thick; plenty of it should be brushed on the surfaces that are to be in contact, as the wood absorbs considerable of it.

In Fig. 20 (*a*) is shown a section through a door stile such as described; the caul is shown at *a* against the veneer *b*, while the core is shown at *c*. Several stiles or rails may be veneered at one time with only outside cauls, but paper should be placed between the veneers. The veneers should be tacked in two or three places to keep them in position until clamped together with handscrews, which should be spaced not more than 6 inches apart; in fact, they can hardly be put too close together. The handscrews are placed at opposite sides alternately, to insure an even pressure on both edges that will drive the glue into the pores of the wood. In paneled work, where hardwood moldings are used, it is desirable to avoid the use of nails to secure the moldings in place.

At *f*, Fig. 20 (*a*), is shown a pine strip glued into the groove of the door stile, against which the panel moldings *g* are mitered and glued at *e e*; then, the polished panels are set in place at *d*, and the other face of the door is molded and glued to *e′ e′*. Another example of door-stile molding and panel is shown in (*b*). The panel *a* is usually made of the same kind of wood as the veneer, but plain. Sometimes, however, the raised face *b c* is veneered with choice wood of finely marked grain, polished and finished before it is placed in the door. All plain-faced material may be clamped and veneered together in quantities, as shown in Fig. 20 (*c*). The core pieces *c* are separated by layers of paper placed between the veneer faces, as shown at *d*, and one operation with the handscrews and the two cauls *a* is sufficient to secure the whole.

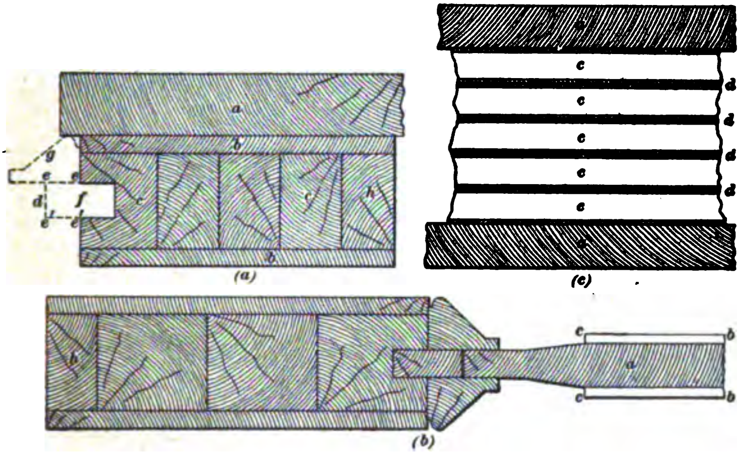


FIG. 20

23. Thin veneers are often found in a badly crumpled condition. In this case, they must be sponged with hot water and squeezed gradually and evenly with handscrews between plain-surfaced cauls, and then allowed to stand until they are in a fit condition to be laid. Sometimes, the same effect is accomplished by placing heavy weights on a caul over the moistened veneers.

24. In order to join two pieces of thin veneer, they must be cut with a sharp knife guided by a perfect straightedge. The pieces are laid on a plane surface with paper underneath, and are tacked at a convenient distance on each side of the joint in such a way as to draw the two pieces together. Then, a strip of strong manila paper is glued over the joint, and the veneer is placed on a suitable straight strip of wood under heavy pressure and allowed to remain until the glue is dry. In laying this jointed veneer, the papered side must be laid outwards. After the veneer has been laid and the glue has become thoroughly dry the paper may be slightly sponged and removed with the scraper.

25. The veneering of a small, circular column may be accomplished with the apparatus shown in Fig. 21. Here, a sheet of tin is used. This sheet has cleats securely nailed to each end, by means of which handscrews can be made to press the heated tin caul and veneer tightly to the surface of the column. The tin should be about ¾ inch shorter than the

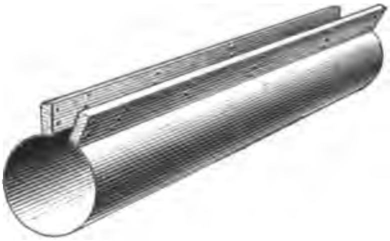


FIG. 21

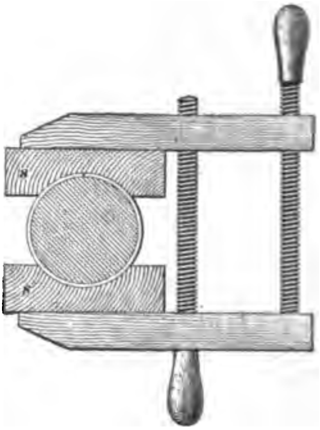


FIG. 22

circumference of the column, in order to leave room for the glue that is squeezed out along the joint. The veneer should be sponged with hot water just before straining it around the column. The column and the tin should be heated before veneering. The advantages of a tin caul are that it requires no waxing and will not stretch. A strip of paper wrapped around the core will be sufficient to determine the length of the veneer, which must be equal to the circumference of the column. To bring the two edges of the veneer together when the tin caul is removed, long, solid cauls are used, as shown at *s*, Fig. 22.

26. A tapering column is veneered in precisely the same manner as a circular column. To find the length and shape of the veneer, however, lay out, as in Fig. 23, *a b* equal to

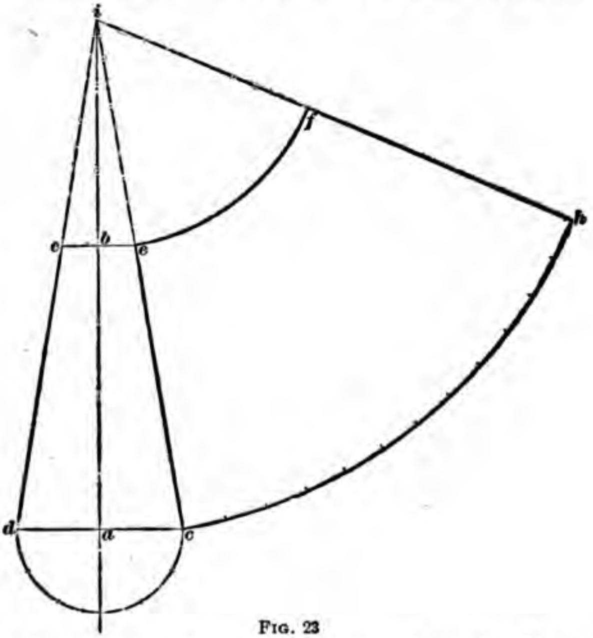


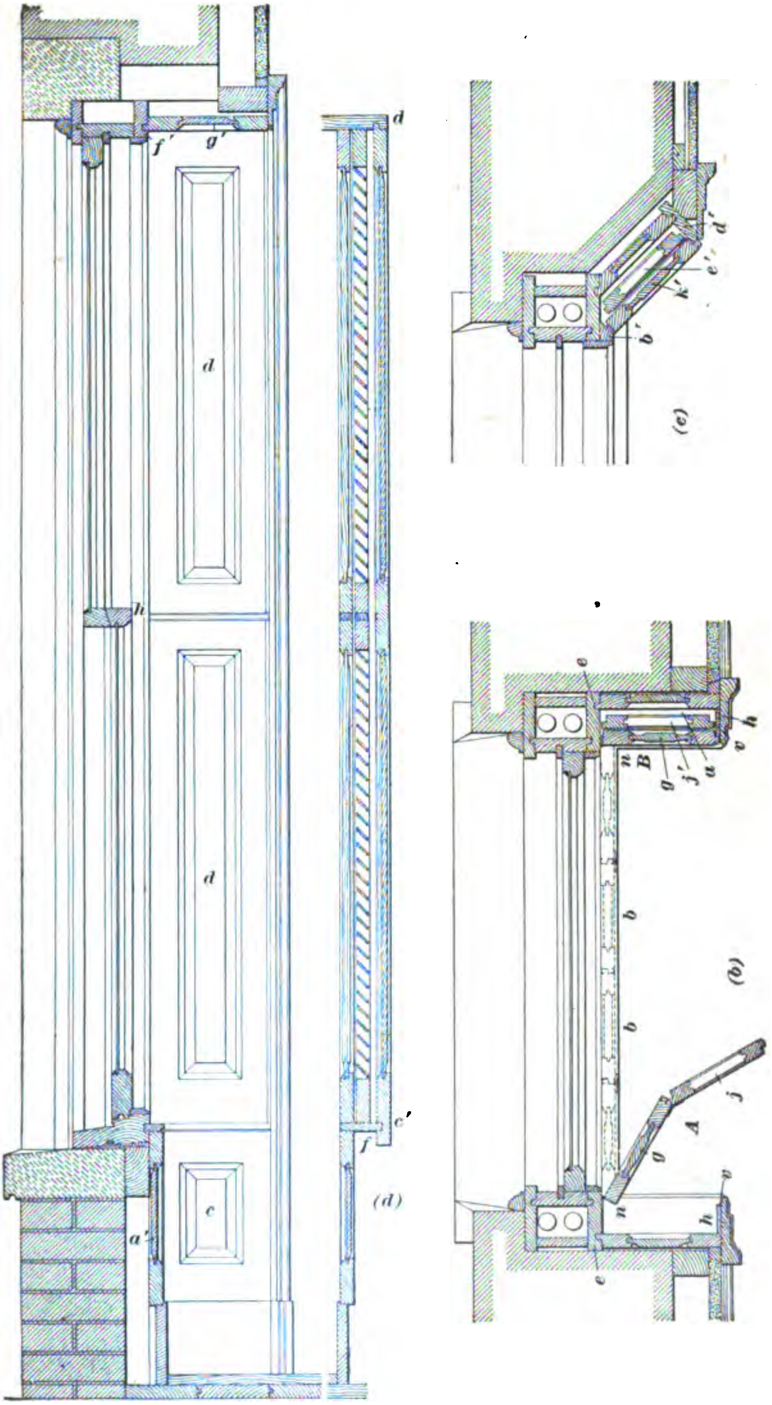
Fig. 23

the height of the column and *c d* equal to the diameter of base. Continue *c e* and *d e* to *i*. From *i* as a center, with *i c* and *i e* as radii, describe the arcs *c h* and *e f*; from *a* as a center, describe the semicircle of the base *c d*. Divide the semicircle into any number of equal parts, and mark these parts twice on the unfolded base line *c h*; connect *h i*; then, *c h f e* will be the shape and exact length of the veneer and also of the caul. The caul, however, must be made to come together about $\frac{3}{4}$ inch short, as previously explained.

BLINDS AND SHUTTERS

27. In order to prevent the strong sunlight from streaming through the windows of a dwelling or other structure, these openings are usually provided with **blinds** or **shutters**, which may be of several different forms or combinations of two or more forms. Blinds are divided into two general classes; namely, *inside blinds* and *outside blinds*. The former may be either *folding blinds* or *rolling*, or *Venetian*, *blinds*, while outside blinds are nearly always of the same general pattern. Blinds solidly paneled are called *shutters*. The method of construction in each case is influenced largely by atmospheric conditions, but the general principle is the same in all cases. Inside blinds are usually made of hardwood to match the trimming of the room containing them, while outside blinds are nearly always framed of pine and painted to protect them from the elements. Outside blinds must also be constructed with consideration of the fact that they are likely to be subjected to rather rough usage through the influence of high winds and rapid changes of temperature.

28. **Inside folding blinds** make a very neat as well as a most useful fitting for the inside of a window, and they should be so arranged that, when closed into their box, the exposed leaf will show a panel finish on the inside of the room, as shown at *d*, Fig. 24 (*a*). These leaves are usually folded into a square jamb, as shown in the plan, Fig. 24 (*b*), although, when circumstances will permit, they are folded into a splayed opening, such as is shown in (*c*), in which case the panel work shows up to better advantage and the room is rendered lighter.



(a)

FIG. 24

In Fig. 24 (*b*), the full plan of the window is shown with the leaves closed into the box at *a*, while the dotted lines at *b* indicate the position of the leaves when opened out of the box and closed over the window sash. The extreme width of the leaves between the outside hanging stiles *n* is 1½ inches more than the width of the window between the pulley stiles, and is divided into four parts, each one of which represents the width of a leaf, or wing. Two of these leaves are usually paneled, as shown at *g*, and the other two are provided with either fixed or movable slats, as shown at *j*. The slatted portion is hinged to and folds behind the panel, as at *A*, and the two then revolve on hinges connecting the paneled leaf to the casing and close into the box with the panel on the exterior, as shown at *B*.

These sections are framed together in one piece, from the inside sill to the window head, in the same manner as the rails and stiles of a door, except that the outer leaf *j* of the blinds is filled with fixed or movable slats, or louvers, instead of paneling, as is the inside leaf shown at *d*, Fig. 24 (*a*).

The space between the window sill and the floor is usually covered with a *panel back*, as shown in section at *a'*, Fig. 24 (*a*); its return under the shutter box is shown at *c*. This panel back is generally paneled similarly to the shutters above, and is contructed in the same manner as the paneled shutters.

In Fig. 24 (*d*) is shown a section through the panel back and blind box. At *f* is shown the bottom of the box, housed into the lining *c'*, which forms the back of the inside of the blind box and is secured at the top by a tongued-and-grooved joint into the soffit piece *d*. This soffit piece is paneled to match the blinds and panel back in the jambs, as shown at *g'*, Fig. 24 (*a*), and is secured by a tongue worked on its edge and let into the window casing at *f'*. The inside lining *e* of the weight box, Fig. 24 (*b*), in the window frame forms the outer lining of the shutter box, and the inner lining of the latter, as shown at *h*, is attached to and forms a part of the interior trim. The paneled shutters *g* are hinged to the hanging stile, as shown at *n*, while the slatted blinds *j* are hinged to *g*, so that the knuckle of the hinge is entirely within the edge of the stile of *g*. This method of hanging permits the blind *j* to swing back sufficiently from the edge of the stile to secure it from any danger of catching on or against the edge of the architrave, or the shutter stop *v*, when the leaves are closed into the box, as shown at *B*. This is still further accomplished by making the leaf *j* ¾ inch narrower than the leaf *g*, so that there will be no tendency for it to become jammed in the box. The rabbeted joint between the two leaves *g* and *j* is only ⅜ inch deep, and is provided simply to secure a light, tight joint.

29. When the jambs of the window are splayed, as shown in Fig. 24 (*c*), there is only a slight difference in the construction of the blinds themselves, although the box requires a little extra attention. At the outside edge of the box, on the side next to the window, the extra hanging stile b' is introduced, to provide a proper depth at the front edge of the box for the paneled shutter k' to shut into. Without this, the leaf would close back no further than in the square jamb shown in Fig. 24 (*b*), unless the edge was beveled to suit the splay. The box jamb d' is also necessary at the inner side of the box, to form a satisfactory stop for the shutter and to make a neat finish to the box itself. In splayed window jambs, the blind c', which folds inside, must be made from 1½ to 2 inches narrower than the exterior shutter k'.

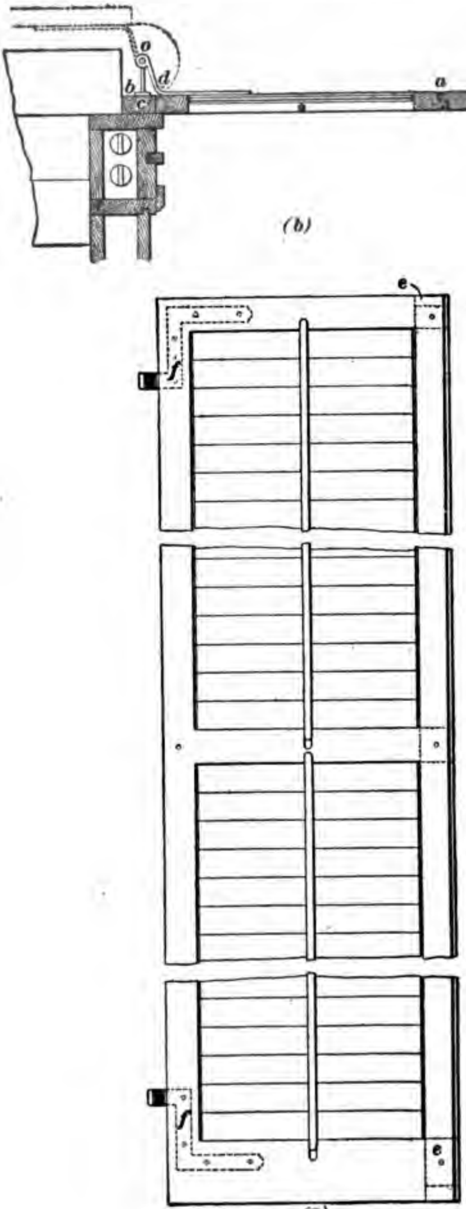
30. When inside blinds are required for a window, it is first necessary to lay out a measuring rod, with the stiles, rails, and panels marked as described for the framing of doors, etc. The entire blind, from the sill to the window head, is laid out and constructed in one piece, and then sawed apart at the center of the meeting rails, as shown at *h*, Fig. 24 (*a*). The leaves are temporarily hinged and hung in place, so as to insure their proper fit, and the marks are then made at the meeting rails, to which the blinds are afterwards sawed, thus forming an independent set to cover the upper and lower sashes.

31. Outside blinds differ from inside blinds only in such details of construction as their more exposed situation requires. In Fig. 25 (*a*) is shown the inside elevation of an outside blind, while in (*b*) is shown its plan. The hanging stile for the blind on the window frame is shown at *c*, and the form of hinge necessary to permit the blind to open around the angle of the brickwork is shown at *b*. The shape of this hinge and its attachment to the blind are shown by the dotted lines at *f*. The angle in the hinges permits them to extend over the joints at the top and bottom rails, and thus add strength to the blind, besides rendering it more secure in high windstorms than would the ordinary hinge.

The extreme length of the arm *o b* carrying the pin half of the hinge permits the blind to swing around the outside of the brick wall clear of the opening, as shown by the dotted lines; but the corresponding length *o d* causes the blind, when opened, to move first in the direction *d a*, and is likely to cause the blinds to bind when they are opened. This tendency, however, is taken care of by the thinness of the metal of which the hinges are made, as they can be easily "sprung" out of place a sufficient distance to permit the blinds to open at the center and swing clear.

32. Outside blinds are laid out with a measuring rod in the same manner as doors and other framed work, the lengths of stiles and rails, the positions and lengths for tenons, and the location of relishes, etc. being all marked on the measuring rod before any of the actual framework is even started. The positions and proportions of the mortises and tenons in this blind are shown by the dotted lines at *e*, Fig. 25 (*a*), as are also the tightly driven pins that hold the joints in place.

As glue would be useless to secure the joints of outside blinds, owing to their exposed situation, the fixed parts are fitted together with white lead. The movable joints of the slats, however, require nothing to make them secure except a proper consideration for the accuracy of construction and the effects of probable expansion and contraction.



(b)

(a)

FIG. 25

33. Fig. 26 shows a section of the top rail of the blind and four of the slats, or louvers. The thickness *a b* of the stile varies, but is never less than 1$\frac{1}{8}$ inches. The holes shown dotted at *d* have a diameter equal to the thickness of the slats, which thickness varies with the size and weight of the blind. The holes are bored from $\frac{3}{8}$ to $\frac{5}{8}$ inch from the outside of the stile, and should be exactly $\frac{1}{4}$ inch deep. The pins on the ends of the louvers are exactly $\frac{11}{32}$ inch in length, thus leaving at each end of the slats $\frac{3}{32}$ inch, to allow for painting and to permit freedom of movement.

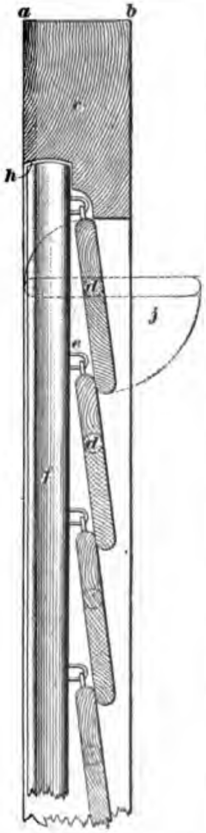


FIG. 26

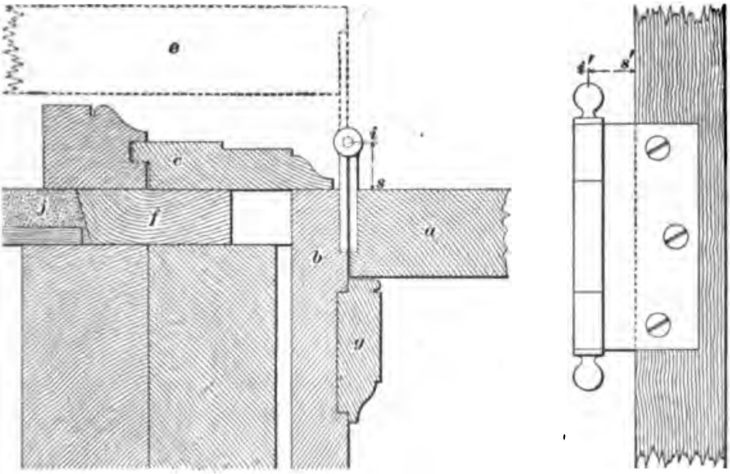
The louvers are operated by a rod that is attached to each slat by means of two **U**-shaped staples, one of which is forced into the middle of the edge of the slat, while the other is driven into the rod itself, as shown at *e*. Thus, when the rod *f* is pulled down, each louver is thrown to the horizontal position shown by the dotted lines *j*, thereby admitting light and air through the blind.

The top stile *c* is cut out, as shown at *h*, to receive the upper end of the rod *f* and the upper staple when the slats are closed in the position indicated in the illustration.

Blinds of this character are made with two, three, or four panels of louvers, according to the height of the window on the stile of which they are hung, each panel being separated by a horizontal rail from the one next above or below, and each set of louvers being operated by a separate rod, as shown in Fig. 25. In the case of an unusually high blind, however, the two upper sets are sometimes operated by one long rod, which extends over both panels and moves in a groove, cut across the separating rail, when the slats are closed.

HINGES AND THEIR APPLICATION

34. Butts, or hinges, are used for hanging doors, inside shutters, lids of chests, boxes, etc. The butt generally used for hanging doors is a *loose-pin butt;* the pin being loose, it can be readily taken out with the fingers, and the door can thus be removed without unscrewing the hinges. To hang the door properly, two hinges—and in case of heavy doors, three hinges—are required, the top one being secured 6 inches below the top of the door, and the bottom one, 10 inches above the bottom of the door. Fig. 27 (*a*) shows a horizontal section through a door casing at the hinge. At *b* is the door jamb, back of which are the grounds *f* extending to the plaster line *j*. At *c* is shown the door trim, and at *g*, the door stop against which the door *a* is closed. The projection *s i* of the hinge to the center of the pivot is the same as *s' i'* of the hinge shown in the elevation (*b*), where one flap of the hinge is shown let in and screwed to the edge of the door. This projection *s' i'* of the hinge, when the door is opened, as shown dotted at *e*, causes the door to swing twice the distance *s' i'*, thereby causing it to clear the



(a) FIG. 27 (b)

trim *c*—a condition always requiring consideration when ordering hinges.

35. Fig. 28 shows an inside window-frame casing at *e*, to which the elbow blind *b* is hung. The blind as it stands

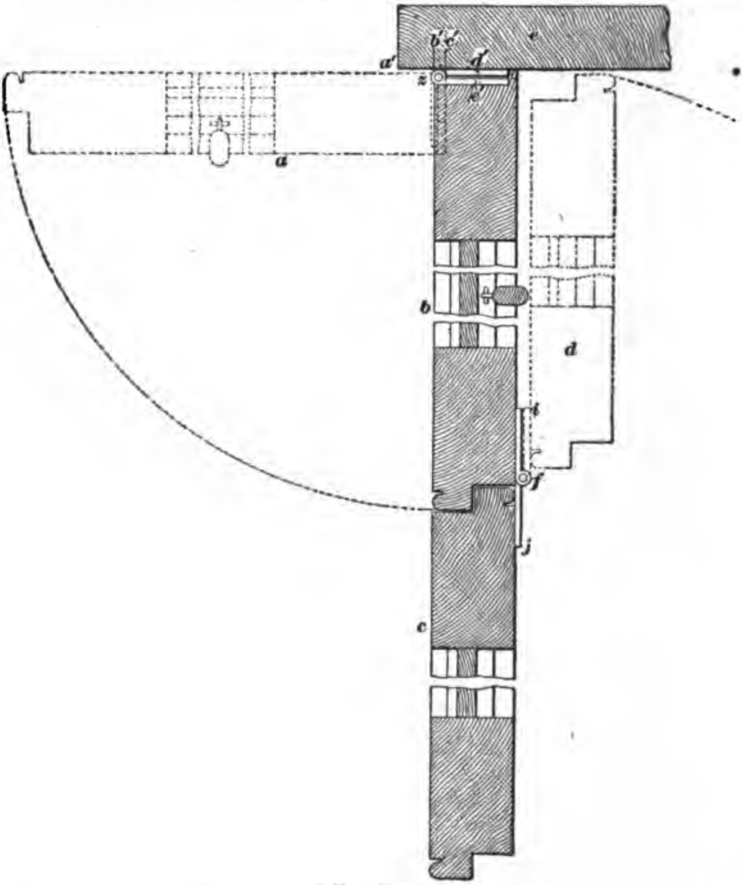


FIG. 28

in the box is shown at *b*, while at *a* it is shown dotted in position as closed across the window. At *c* is shown the flap blind in line with *b* when open, and at *d*, its position when folded in the box. In hinging the elbow blind *b* to the casing *e*, the whole thickness of the hinge is let into the edge of the blind, and the flap of the hinge is screwed to the face of the casing *e*. The knuckle of the hinge should project just beyond the face of the blind *b*, as at *z*. When the hinge is placed as shown, making *a′ b′* $\frac{1}{2}$ inch from the edge of casing to face of blind, then, when *b* swings on its hinges to the position *a*, the edge of the blind will be at *c′*, which is $\frac{3}{16}$ inch from *b′*, or $\frac{11}{16}$ inch from *a′*; therefore, in making the blinds, the width must be taken from *c′* in order to

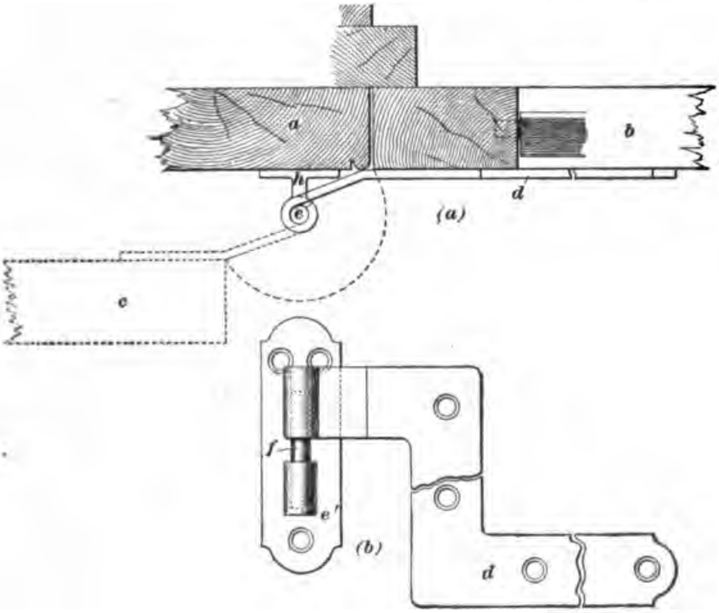


FIG. 29

show the $\frac{1}{2}$-inch margin of the casing when the blinds are open. The flap hinge *i f j* is screwed to the inside face of the blinds, thus keeping the knuckle of the hinge all on the elbow blind *b*. This is done to prevent the edge of the flap blind *d* from striking when folding the two blinds in the box as previously explained.

36. Hinging Outside Blinds.—Fig. 29 shows a plan of the blinds of a frame house. At *b* is shown the position of the blinds when closed, and at *c* is shown the blind when opened. At *a* is shown the hanging stile to which one-half of the hinge is screwed, as at *h*. The hinge is in two parts, as shown at (*b*), and consists simply of an iron strap *d* with a socket to fit around the pivot *f* that is secured to the other half of the hinge. The iron strap *d* is screwed to the blind *b* and is secured by means of the pivot *f* in the socket *e*.

Outside blinds of brick houses require a hinge very little different from that of a frame house, but the hinge must throw the blind out farther, in order to clear the brick corner.

INTERIOR FITTINGS

37. Though the location of the fixtures and the arrangement of the pipes in the bathroom are usually considered only in connection with the plumbing work, the finish of these details and the general interior treatment of the rooms are entirely in the hands of the joiner.

38. Washtubs.—Washtubs are fixtures that the joiner is frequently called on to build, and Fig. 30 shows a method of constructing them. In (*a*) is shown a plan of one of these tubs, in (*b*) a vertical section through the tub, and in (*c*) the plan of the crosspiece under the tub and its joint with the turned leg, as shown at *x* in the vertical section. These fixed tubs are usually built in either a kitchen or a laundry, and consist of from two to four divisions. In (*a*) is shown the end tub of a set. The partition *a* and end-piece *b* are shown housed into the front and back pieces *c* and *d*. All of these pieces *a*, *b*, *c*, and *d* are 2 inches thick, and are bedded at the joints with white lead. The bottom is dadoed into the sides, and is secured by means of lag-screws, shown at *e*, Fig. 30 (*b*); this joint is also set in white lead. At $y y'$ is shown a paneled cover over the tubs, hinged with a brass hinge at y', while behind the tubs is shown a 2-inch space for pipes, etc. Extending over three-fourths of the thickness of the back piece d' is a wooden cap *f*, which finishes the top against the wall. At *g* is shown a $2'' \times 2\frac{1}{2}''$ support against the wall. This support carries one end of the 1½″ × 2½″ beam *h* and the other end of the beam rests on and is dovetailed into the 4-inch leg *k*, as shown in the plan (*c*) at *k′*.

39. Butler's Pantry. There is no part of a private residence where the joiner is called on to do so much work in a small space as in the **butler's pantry.** The pantry must contain a long table for holding the dishes, both before and after their service in the dining room. A sink in which to wash dishes, well lighted from an adjacent window, must also be provided, while a dresser opposite or over the long serving table will receive them after they have been washed.

Fig. 31 shows the plan of a butler's pantry suitable for a private house. The details of such a plan would be applicable to either city or suburban dwellings. The entrance *a* is provided with a sliding door, for economy of space. On the left at *b* is the long service table 18 inches wide, where the

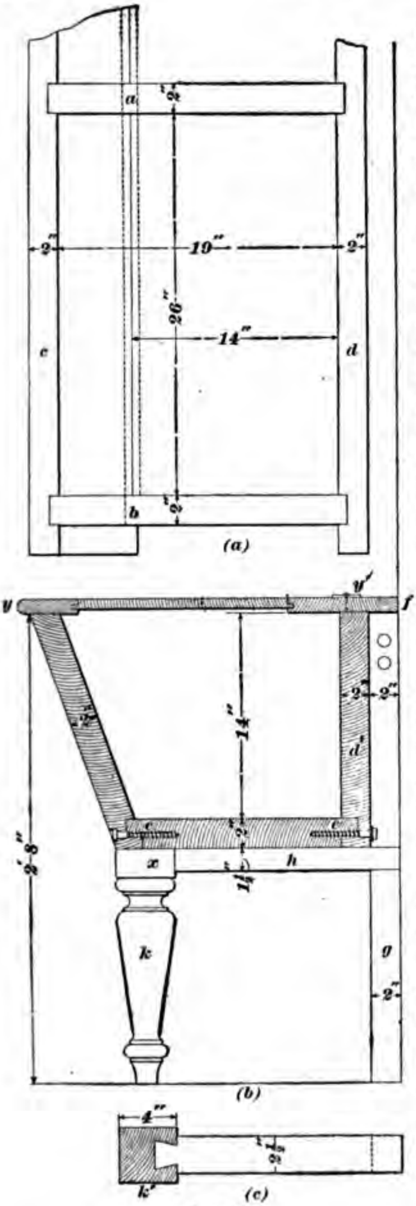


Fig. 30

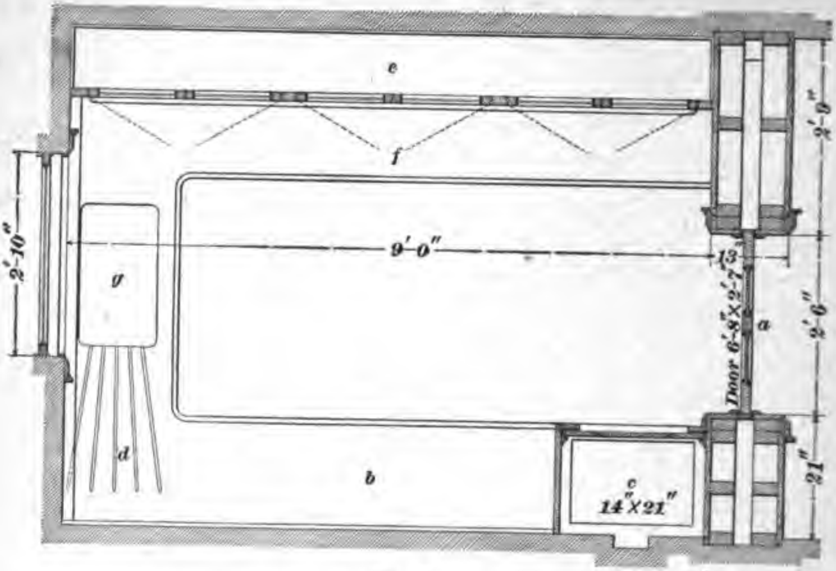

e
f
2'-10"
g
9'-0"
13"
Door 6'-8"×2'-7"
a
2'-8"
2'-6"
21"
d
b
c
14"×21"

FIG. 31

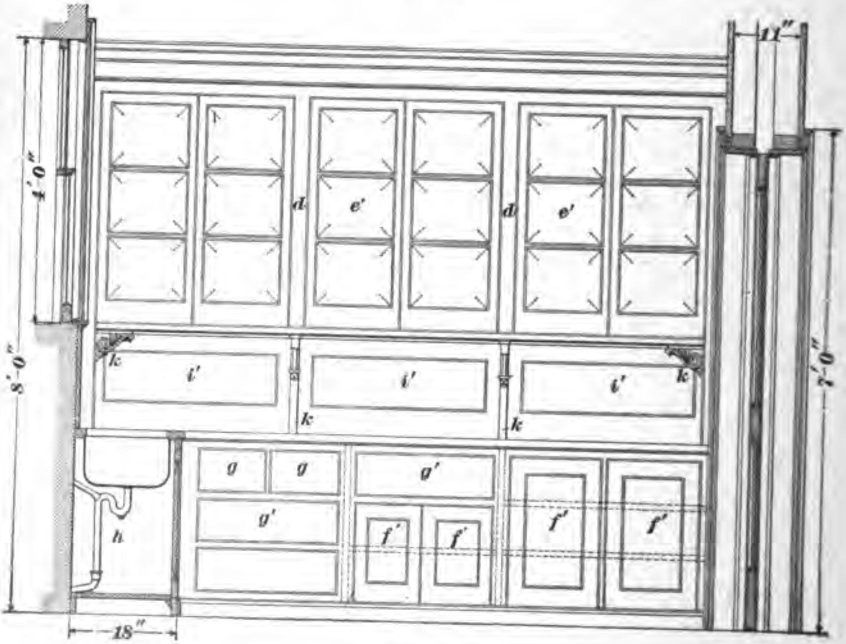

11"
4'-0"
d
e'
d
e'
7'-0"
8'-0"
k
i'
i'
k
i'
k
k
g
g
g'
g'
f'
f'
f'
f'
h
18"

FIG. 32

dishes are placed or the carving is done before the food is served in the dining room. At one end of this table is the dumb waiter *c*, while at the other end, at *d*, is the drip board of the sink. Opposite the serving table is the dresser *e* for the dishes, below which are closets *f*, and drawers for silverware, dishes, etc., as shown more in detail in Fig. 32.

40. There is no work in the construction of these pantry fittings that has not already been described. The glazed doors of the dresser *e'*, Fig. 32, are constructed in the same manner as a hinged window sash. When the dresser is not over 7 feet long, it is sometimes advantageous to close the front with three glazed sashes. These sashes are plowed with a groove in the top and bottom rails, and are arranged to slide the full length of the dresser on hardwood or metal tracks, which are secured just far enough apart to permit the sashes to clear one another in sliding; or, they may be made in pairs and hinged as shown on the elevation. The shelves in the dresser may be fixed permanently in place and varnished on both sides, so as to prevent any dust from sticking to them or collecting around the dishes. The drawers *g'* are provided for silverware, such as forks, knives, spoons, etc., and the shelves in the closets underneath are for linen and larger pieces of tableware that cannot conveniently be put in the upper part.

The glazed closets *e'* are placed about 18 inches above the top of the linen closets *f'*, thus leaving a long, narrow sideboard between, the wall side of which is paneled, as shown at *i'*, with plain, flat, unmolded panels, similar to those in the doors below. The glazed closet is secured against the wall, but is supported by means of either metal or wooden brackets *k*, placed one at each end of the closet and one under each of the mullions *d*.

In the section shown in Fig. 33, the window at the end of the pantry is located at *a'*, and immediately under the window is the sink, as shown at *g*, Fig. 31. The board shelves over the serving table are shown in section at *b'*, Fig. 33, and a section through the dresser shelves is shown at *e'*.

When the pantry is built in a suburban residence, it partakes more of the character of a storeroom, and requires at least one chest of smaller drawers, as shown at *g*, Fig. **32,** for the storage of coffee, tea, sugar, spices, etc., while at one end must be provided a proper compartment for a barrel or a bag of flour.

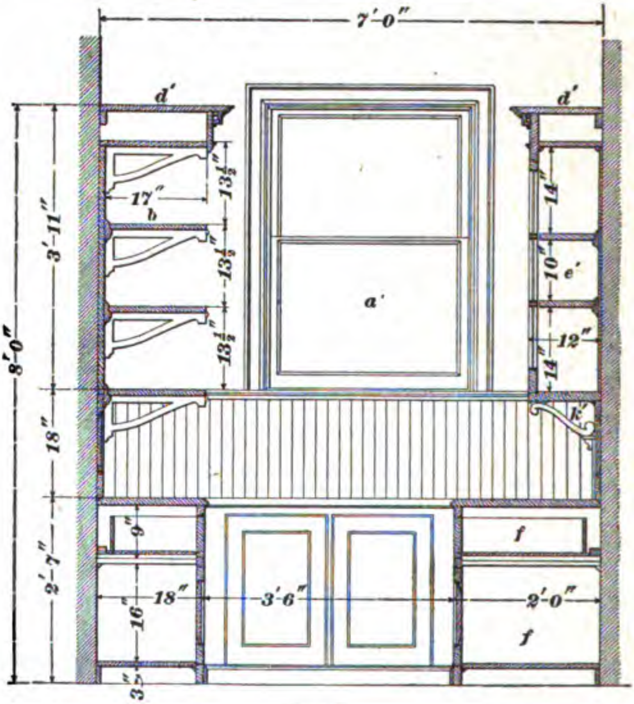


Fig. 33

41. Refrigerators.—In Fig. 34 is shown the plan of a **refrigerator,** the front and side walls of which are framed of 2" × 4" studs *a*, spaced in two sets, with 6 inches between their inside and outside faces. Over these studs a layer of sheathing *b* is secured diagonally to brace the structure, and over the sheathing a course of resin-sized paper *c* is spread to cover all joints. The inside and the outside of the refrigerator are then lined vertically with $\frac{7}{8}$" × 3" beaded stuff, as shown at *d* in the plan, and at *d′* in Fig. 35. The open space *e*, Fig. 34, between the interior and the exterior walls must be filled with charcoal, dry sawdust, mineral wool, or some other non-conducting material. The spacing of the studs alternately, so as to receive the sheathing of the inside and outside walls independently, prevents any solid connection between the interior and exterior walls, and thus retards the transmission of heat.

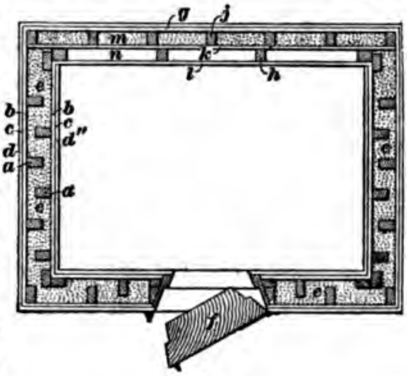


Fig. 34

The door should be beveled, as shown at *f*, so that it may open easily and still be perfectly air-tight when closed.

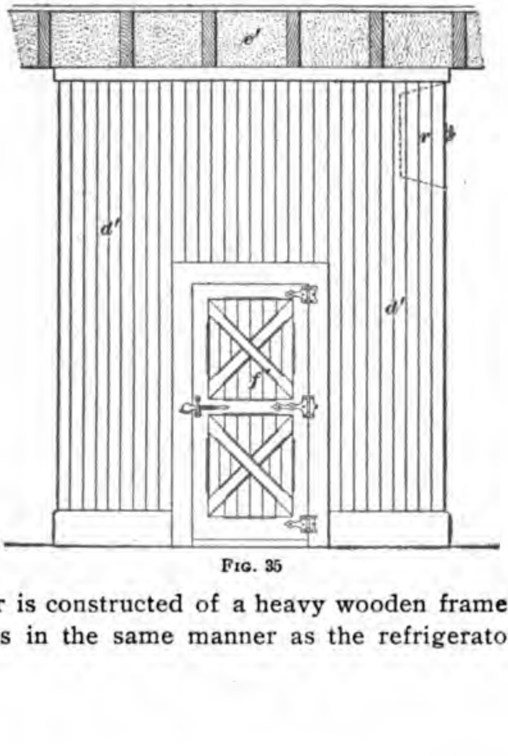


Fig. 35

This door is constructed of a heavy wooden frame lined on both sides in the same manner as the refrigerator proper, and must also be filled with non-conducting material. The dimensions of the door should be as small as the purposes of the refrigerator will permit, and the door should be secured, when closed, by means of a Condit "ice-box lever," the action of which tends to force the door tightly into the opening.

The rear wall is studded and sheathed on the outside similarly to the side walls, as shown at *g*, Fig. 34; but the inner studs *h* are spaced about twice as far apart as the outer row *j*, are separated from the outer row by a single thickness of sheathing *k*, and are sheathed on the inside by a similar single thickness *l*. The spaces *m* between the outside studs are filled with charcoal or other non-conducting material, while the spaces *n* between the interior studs are left open to form air ducts, as shown at *n'* in the section, Fig. 36.

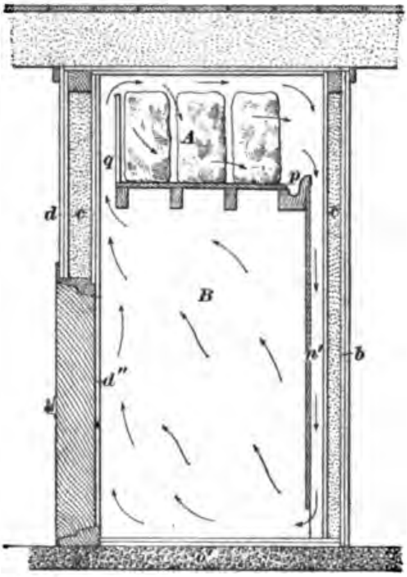


Fig. 36

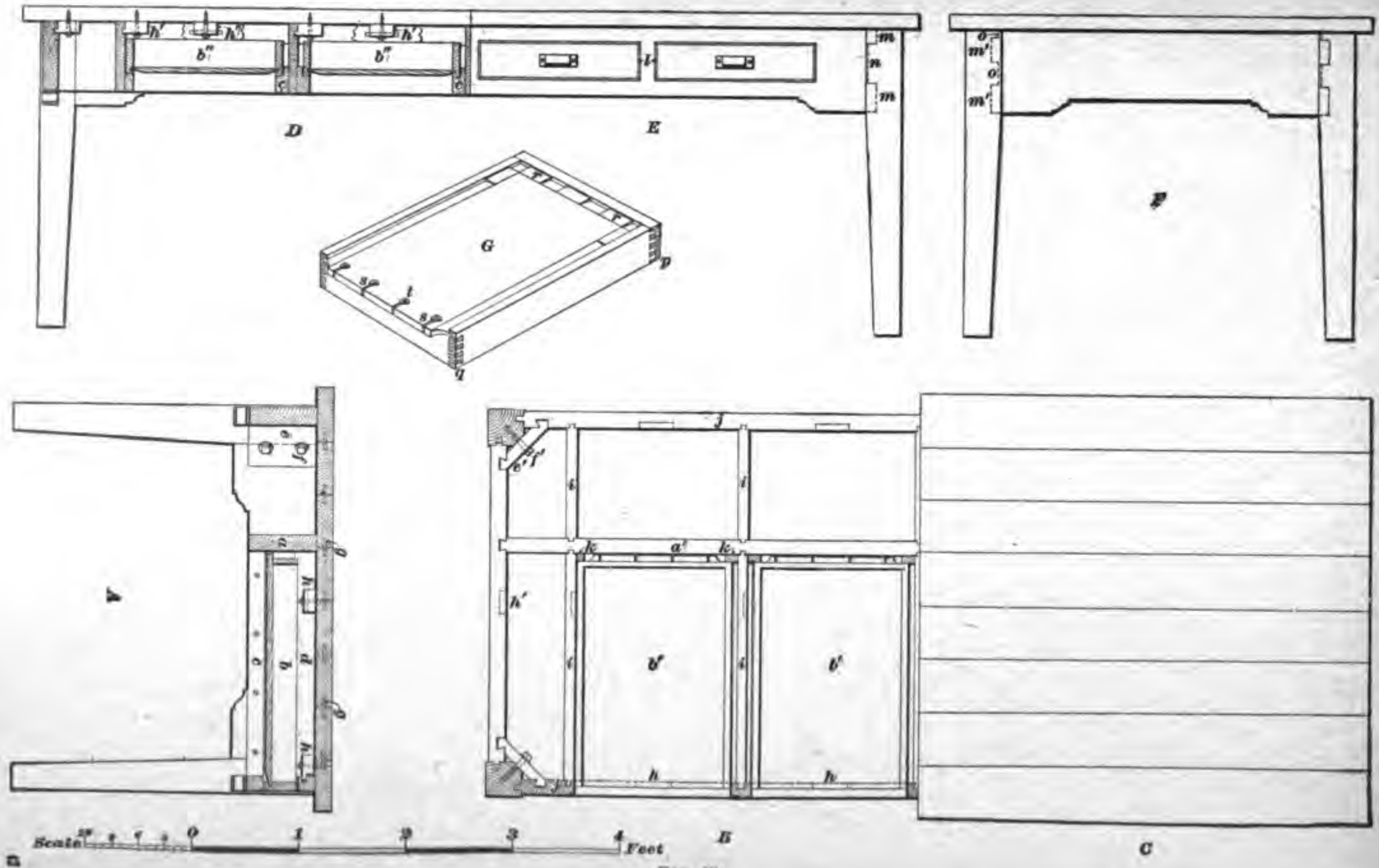
Fig. 36 shows a vertical section of the ice box. The interior lining of the front is shown at *d''* and the exterior covering at *d*, while at *c* is shown the charcoal or other filling. About 2 feet 6 inches below the top is built a floor to support the ice, along the front of which an opening is left, to permit the cold air to circulate. This floor is inclined slightly toward the back of the ice box, so that the water from the melting ice will drain to the trough *p*. The water may then be conveyed by means of a copper or lead pipe discharging into an open sink or other suitable point of delivery. The waste pipe should be trapped, in order to prevent a circulation of the outer air. The floor of the ice receptacle may be covered with ¼-inch boiler plate for hard usage, or heavy zinc may be used. By the arrangement shown, the cold air from the ice box falls through the air ducts *n′*, and after cooling the interior of the refrigerator *B*, it rises through the opening *q*, as shown by the arrows, and becomes again cooled by contact with the ice at *A*. A circulation of cold air is thus constantly maintained, and the interior of the refrigerator is kept at a low temperature.

In Fig. 35—the elevation of the front of the refrigerator—the entrance door is shown at *f′*, while at *r* is shown the dotted outline of the door at the side of the ice box for the purpose of inserting the ice. The space between the top of the refrigerator and the ceiling should be filled with non-conducting material, as shown at *e′*, to protect the ice stored in the ice box.

42. Serving Tables.—Fig. 37 shows a kitchen **serving table,** 4 feet wide by 8 feet 8 inches long, and 2 feet 8 inches high. Four drawers, 24 inches deep, may be placed along one side, but the wide span between the legs, a heavy load on top, the weakening of the front rail by the insertion of the range of drawers, and a top, 4 feet wide, which would tend to warp from the heat of the kitchen, are the points that require consideration.

Plain, substantial, sound construction, with staying qualities are required. To secure as much rigidity as possible in the front, or drawer rail, it is necessary to make the framework of some hardwood, and the joiner should select some well-seasoned prime ash, this material being well adapted for the purpose.

In order to proportion the legs to the depth of rail required, they should be made 4 inches square at the head and reduced to 3 inches square at the foot. The rails should be 1⅞ inches thick and 8 inches deep, which depth should be increased to 9½ inches at the shoulders, so as to render the junction with the legs inflexible, while the increase should be treated as a corbel, or bracket. The end and back rails should be of solid material, while the framing of the front rail as well as that


D
E
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h''
b''
c
l
m
n
o
m'
p
q
s
t
a
a'
b
b'
d
e
f
e'
f'
g
h
i
j
k
Scale
12
9
6
3
0
1
2
3
4
Feet

Fig. 87

of the various other sections should be done as indicated in Fig. 38. A $\frac{1}{8}$-inch bead should be run on the edges of the vertical and horizontal members, around the drawer panels, the beads being mitered at the angles. An intermediate longitudinal rail should be introduced behind the drawers, as

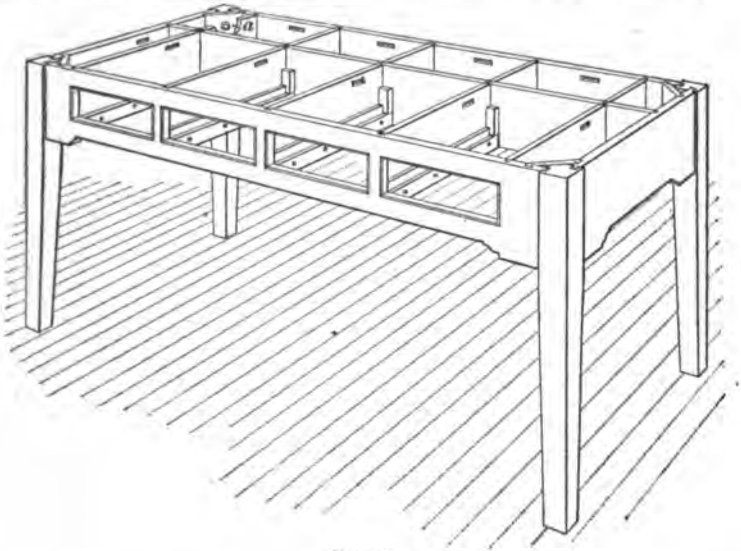

FIG. 38

at *a* in *A* and at *a′* in *B*, Fig. 37, so as to compensate for the loss of strength in the front rail.

The top should be made of $1\frac{3}{8}'' \times 6''$ clear, well-seasoned white pine, heart stock, the edges being carefully jointed and doweled with $\frac{7}{16}$-inch hardwood pins at 7-inch centers.

43. At *A*, Fig. 37, is shown a transverse section, taken near the end of the table, so as to show both the drawer in its pocket and the method of uniting the rails to the legs. At *b* is shown the drawer, while *c* is the lower runner, or cleat, on which the drawer slides. The upper guide, which would be placed at *d*, to prevent the drawer from tilting when drawn out, is omitted, so as to show other more important details. At *e* is shown the angle plate of hardwood, which is dovetailed into the rails as shown at *e′* in *B*. This angle plate is attached to the leg by means of two lagscrews *f*, which, being drawn home, keep the shoulders of the rails in the closest contact with the legs. The dowel-pins in the top are shown at *g*. The top should not only be securely fastened to the rails, but provision must be made for its expansion and contraction. This is effected by the use of the tongued buttons *h*. On the center line of the table, the buttons are screwed to the top, while their tongues pass into grooves cut out of the cross-rails. These grooves must be made just the width of the button, so that the center line of the table will not change its position. Similar buttons are placed along each side of the table, but care should be taken that their shoulders are kept clear of the rail, and that their tongues are of sufficient length, so that, under shrinkage, they will still keep in the groove. The principle involved is similar to that of a panel in a framed door, wherein the panel may *come* and *go* without straining the joints of the framework in which it is contained.

At *B*, Fig. 37, is shown a plan of one-half of the framework looking downwards, in which the cross-rails *i* are dovetailed into the front and back rails *j* and into the intermediate one *a'*. These keep the long rails straight and in a fixed position. The drawers *b'* are in place, and the blocks are so set that the fronts will always be flush with the framing of the rail. At *h'*, near the upper edges of the rails, are located the grooves for the buttons.

At *C* is shown a half plan of the top, looking downwards. This view shows one-half the length of the boards and the number required in the width.

At *D* is shown a sectional elevation of one-half of the table taken through the framework, in which the drawers are shown at *b''*. The runners *c* are rabbeted, making the width between sinkings equal to that of the muntins *l*, in *E*, so that the pocket is kept at a uniform gauge. The upper guide strips are also omitted in this section.

At *E* is shown a half elevation of the exterior. This view shows the relative position of the rail tenons *m*, which pass about 1½ inches into the mortises prepared for them in the legs. The tongues on the edge of the framing at *n* pass into the leg only ½ inch. The bridge between the mortises makes the leg stronger; otherwise, the cheeks of the mortises would be liable to spread and lose their grip on the tenons.

At *F* is shown an end elevation, in which it will be observed that the tenons are arranged somewhat differently. *Relishes*, or shoulders, *o* are formed at the root of the tenons *m'* for the same reason as was given for the depth of *n*, in *E*.

At *G* is shown a perspective view of a drawer, with its bottom upwards. This view shows the mode of uniting the parts, whereby a firm frame is obtained, and illustrates the course followed to provide for the expansion and contraction of the bottom. The dovetail pins are shouldered at the front, and open, or exposed, pins are used at the back. As the length of the drawer is less than its depth, the grain of the wood is run parallel with the front. By inserting glued blocks *r* adjacent to the front, close union is effected between the drawer bottom and the front. By this means, the front will not yield under hard usage, and a close joint will always be a certainty. The back edge of the bottom has slots *s* through which are passed screws *t* into the back rail. The screws are provided with washers, so that the bottom of the drawer may move readily with change of temperature.

44. Fig. 38 shows a perspective view of the framework of the table preparatory to attaching the top, and should give a clear idea of its construction. At *a*, a portion of the cross-rail is omitted to show the angle plate and lagscrew device. All junctions should be liberally glued, and, where practicable, should be kept under clamp pressure until the glue has set. Where heavy tables over 10 feet in length are required, it is well to provide an intermediate leg on each side, so that there will be six supports instead of four, thus assuring steadiness. Tables constructed in the manner just described are also well adapted for warehouse purposes.

Where such tables are required to be built on the *knock-down* principle, whereby the legs can be removed and packed in the upper framing of the table top, the tenons *m*, Fig. 37, *E*, are omitted and only the tongues *n* made to pass into grooves cut ½ inch deep in the adjacent sides of each leg. By this method, the legs can be slipped in place and rigidly secured by the legscrews passing through the angle plates. For small tables with narrow rails, the tongues may be dispensed with, and the rails made simply to butt against the legs.

45. **Drawer Slides.**—If drawers that have been used for many years are examined, it will be noticed that when they are pulled out the front portion of the drawer drops down, and many "bobbing-up-and-down" movements have to be made before the drawer can be replaced. This is caused by the wearing of the upper edges of the drawers toward the back, and can only be overcome by providing traveling slides, which serve as bearers, or supports, for the drawers. By this means, the drawer is supported and kept in a practically horizontal position, even when it is drawn out of the case to nearly its full depth.

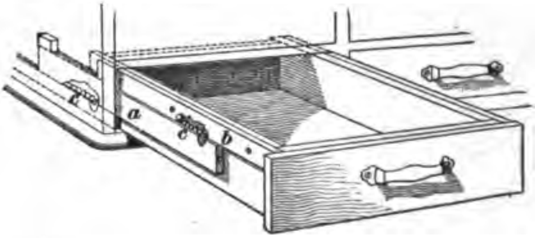

FIG. 39

Such an arrangement is shown in Fig. 39, where *a* is the traveling slide that passes out and in the case by operating the drawer. The weight of the drawer is sustained by the slide *a*, on which travels a cleat *b* attached to the side of the drawer. The slide *a*, in turn, is supported by a cleat secured to the cheek of the drawer pocket. It will thus be seen that there are two planes of friction, one between the slide *a* and the drawer cleat *b*, and the other between *a* and the lower cheek cleat. This is known as the Kimball system of drawer slides, and consists in making the slides and cleats of selected hardwood ½, ⅝, or ¾ inch thick, according to the character and weight of the drawer, and grooving their upper edges with segmental grooves and inserting in these grooves a series of steel balls *c*. The grooves are made deep enough to prevent the balls from falling out when the drawer is removed for dusting, etc. It is not absolutely necessary to make the slides ball bearing, as the series of slides answers for all ordinary purposes.

46. Conclusion.—There are many other details of joinery that have not been separately described, but the principles of construction on which their framing is based are practically the same as those herein discussed. It is necessary to learn to apply principles rather than to memorize methods. When a problem in any form of construction arises, do not try to solve it in a certain manner, simply because it has always been done so before, but endeavor to comprehend the conditions governing the case, and study the form of joint and framing best suited to each particular case—act intelligently, independent of traditional methods.

THE STEEL SQUARE

(PART 1)

PRINCIPLES OF APPLICATION

DESCRIPTION OF THE SQUARE

1. Among the many tools employed by mechanics, there is probably none so useful as the **steel square.** Notwithstanding the mass of marks and figures, there is nothing about a steel square that is complicated or that requires a knowledge of higher mathematics to enable it to be used in ordinary practice, and after a few hours of careful study and examination, every mark and figure should be clearly understood. There are a number of ways of marking the square, which depends on the design or type and on the purpose for which it is to be used. These markings, however, in no way affect the principles of application, and when these principles are once thoroughly understood, any make of square can be accurately used, provided, of course, that the instrument is true.

2. Parts of a Square.—The long arm of a square is called the **body,** or **blade,** and in referring to this part of the instrument, preference will be given to the name *body*. The short arm is called the **tongue,** and the junction between the body and the tongue, on the outer edge, is called the **heel.** The body of a standard steel square is 24 inches long and 2 inches wide, and the tongue is from 14 to 18 inches long and 1½ inches wide. In some inferior grades of squares,

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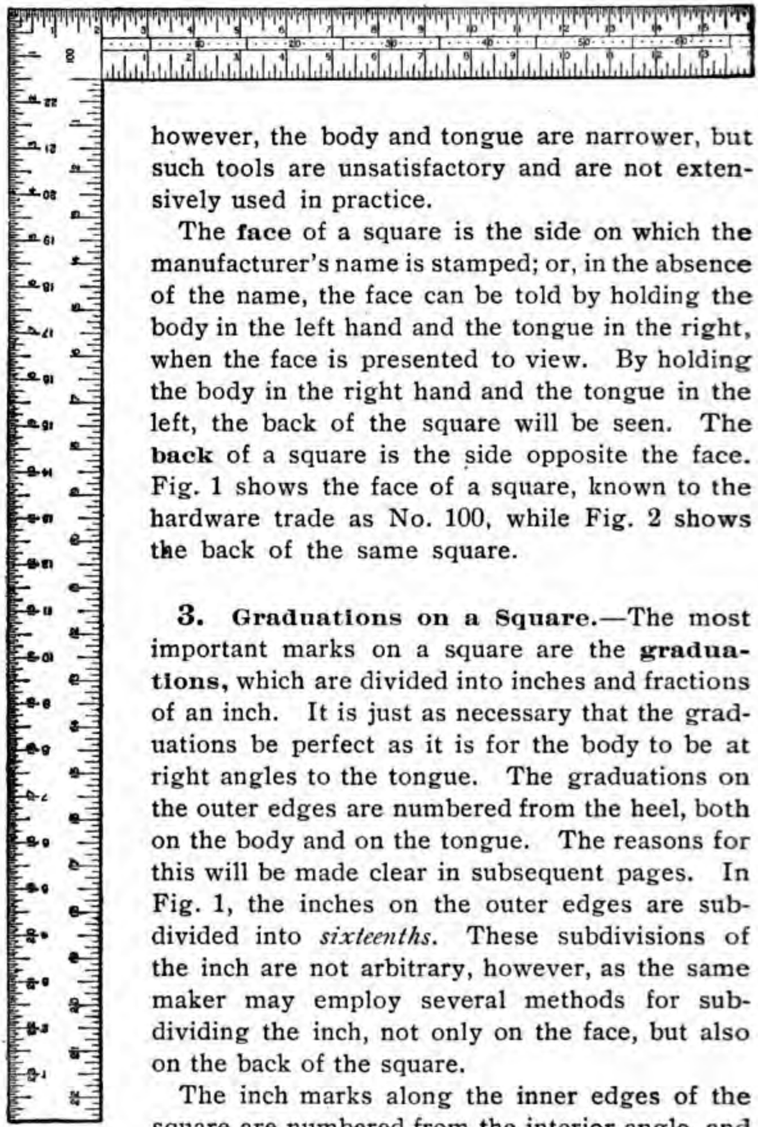


FIG. 1

however, the body and tongue are narrower, but such tools are unsatisfactory and are not extensively used in practice.

The **face** of a square is the side on which the manufacturer's name is stamped; or, in the absence of the name, the face can be told by holding the body in the left hand and the tongue in the right, when the face is presented to view. By holding the body in the right hand and the tongue in the left, the back of the square will be seen. The **back** of a square is the side opposite the face. Fig. 1 shows the face of a square, known to the hardware trade as No. 100, while Fig. 2 shows the back of the same square.

3. Graduations on a Square.—The most important marks on a square are the **graduations,** which are divided into inches and fractions of an inch. It is just as necessary that the graduations be perfect as it is for the body to be at right angles to the tongue. The graduations on the outer edges are numbered from the heel, both on the body and on the tongue. The reasons for this will be made clear in subsequent pages. In Fig. 1, the inches on the outer edges are subdivided into *sixteenths.* These subdivisions of the inch are not arbitrary, however, as the same maker may employ several methods for subdividing the inch, not only on the face, but also on the back of the square.

The inch marks along the inner edges of the square are numbered from the interior angle, and in Fig. 1 are subdivided into *eighths.* As the width of the body of a square is in even inches, the inch

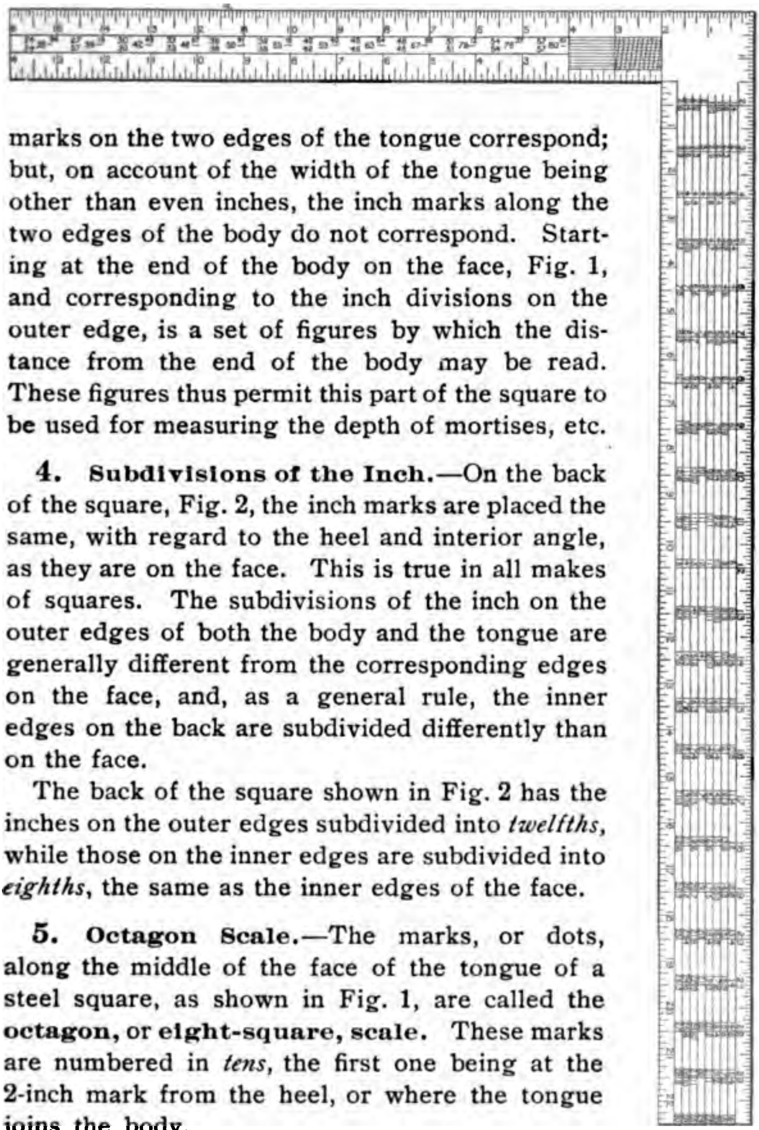


Fig. 2

marks on the two edges of the tongue correspond; but, on account of the width of the tongue being other than even inches, the inch marks along the two edges of the body do not correspond. Starting at the end of the body on the face, Fig. 1, and corresponding to the inch divisions on the outer edge, is a set of figures by which the distance from the end of the body may be read. These figures thus permit this part of the square to be used for measuring the depth of mortises, etc.

4. Subdivisions of the Inch.—On the back of the square, Fig. 2, the inch marks are placed the same, with regard to the heel and interior angle, as they are on the face. This is true in all makes of squares. The subdivisions of the inch on the outer edges of both the body and the tongue are generally different from the corresponding edges on the face, and, as a general rule, the inner edges on the back are subdivided differently than on the face.

The back of the square shown in Fig. 2 has the inches on the outer edges subdivided into *twelfths*, while those on the inner edges are subdivided into *eighths*, the same as the inner edges of the face.

5. Octagon Scale.—The marks, or dots, along the middle of the face of the tongue of a steel square, as shown in Fig. 1, are called the **octagon, or eight-square, scale.** These marks are numbered in *tens*, the first one being at the 2-inch mark from the heel, or where the tongue joins the body.

The octagon scale is used as follows: For instance, it is required to make an octagonal, or eight-sided, post from a piece of timber 10 inches square. In Fig. 3, *a b c d* is the butt of a square stick of timber 10 in. × 10 in. Scribe the lines *e f* and *g h* through the center, parallel with the sides and at right angles to each other. With the compasses, take as many spaces from the scale as there are inches in the width of the stick. In this case, the stick is 10 inches square; therefore, take 10 spaces and lay off this distance on each side of the point *f*, thus fixing points *a′* and *d′*. In the same manner, locate the points *a″* and *b″*, *b′* and *c′*, and *c″* and *d″*; then, scribe the lines *a′ a″*, *b′ b″*, *c′ c″*, and *d′ d″*. Cut off the corners marked *A*, *B*, *C*, and *D*, but before doing so, scribe the lines *a′ a′* and *a″ a″* on the sides of the stick, as shown in Fig. 4. The rule always to be observed is as follows:

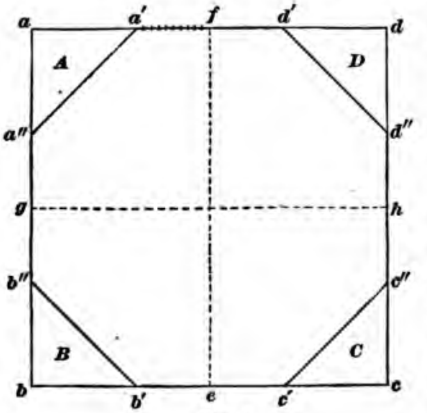


FIG. 3

Rule.—*To make an octagonal post out of a square stick of timber, set off from each side of the center line on each face as many spaces from the octagon scale as the timber is inches square. These points represent the angles of the octagon.*

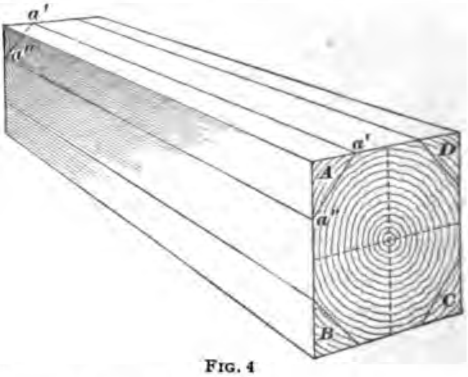


FIG. 4

If the timber is 6 inches square, take 6 spaces from the scale and lay them off as described. Should the timber or other surface be larger than the number of divisions in the scale, the measurements may be doubled or trebled, as the case may require.

6. Diagonal Scale.—The parallel lines on the back of the tongue of a square, Fig. 2, near the junction with the body, are called the **diagonal scale.** This scale is used for setting the dividers to more minute divisions than the primary divisions of the scale. In Fig. 5, which is an enlarged view of the scale shown in Fig. 2, the scale is first divided into 2 inches by the vertical lines. One of these inch divisions is next subdivided into tenths on the upper and lower horizontal lines, and diagonal lines are drawn, so as to join each upper tenth with the next consecutive lower tenth. The horizontal lines are made $\frac{1}{10}$ inch apart, and as each diagonal line crosses the 10 equal spaces formed by the horizontal lines and advances $\frac{1}{10}$ inch in crossing, it is plain that, for 1 space, it will advance $\frac{1}{100}$ inch. Hence, by scaling from any horizontal line, the required hundredths in addition to the tenths marked above may be obtained.

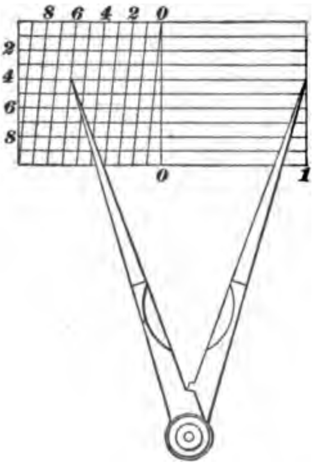


FIG. 5

The dividers shown in the illustration are set to $1\frac{64}{100}$ inches, and this distance is obtained as follows: From *0* to *1* on the lower line is 1 inch, and from *0* to *6* on the upper line is $\frac{6}{10}$ inch; then, by following the diagonal line from *6* to where it crosses the horizontal line marked *4*, $\frac{4}{100}$ inch more is obtained, making the total distance $1 + \frac{6}{10} + \frac{4}{100} = 1\frac{64}{100}$ inches. If, instead of stopping at the horizontal line marked *4*, the dividers are continued down the diagonal line to halfway between the horizontal line marked *4* and the one next below, they will mark $\frac{5}{1000}$ inch more, making the total distance $1\frac{645}{1000}$ inches.

While such minute divisions on the square would not be practicable to use in laying out work on a job, yet the user of a square might possibly want to scale a map, in which case it would be necessary to get these very small divisions. On some squares, the diagonal scale is omitted, and 1 inch graduated into hundredths is substituted.

7. Brace Scale.—The numbers on the middle of the back of the tongue of a steel square, extending from the diagonal scale to the end, as shown in Fig. 2, constitute the **brace scale.** The equal numbers placed one over the other represent the *run*, or, in other words, the two sides of a right triangle, while the numbers at the right represent, in inches and hundredths of an inch, the length of the third side, or hypotenuse. Thus, the exact length of a brace between shoulders having a run of 45 inches on a post and a run of 45 inches on a beam is $63\frac{64}{100}$ inches. These figures are obtained from an inspection of the scale. By referring to Fig. 2, the figures $\frac{45}{45}$ *63.64* will be found, which shows that 63.64 inches is the diagonal, or hypotenuse, of a right triangle having two equal sides each 45 inches long. The figures on the brace scale vary in different makes of squares. On some squares, the run on the post is not always the same as the run on the beam.

8. Scale for Board Measure, or Essex Board Measure. On the back of the body of the square, Fig. 2, is shown the scale for board measure. A thorough knowledge of the use and application of this scale may be gained by studying it for a few minutes, and, when once understood, the contents, in board measure, of almost any board or plank may be read off directly from the scale.

The figure *12* in the graduation marks on the outer edge represents a 1-inch board 12 inches wide, and is the starting point for all calculations. The smaller figures *8*, *9*, *10*, *11*, *13*, *14*, and *15* under the *12* represent the lengths of boards. The *12* following *11* does not belong to this vertical row of figures, as the contents of a board 12 feet long is read by the figures on the graduations. For instance, a board 12 feet long and 11 inches wide contains 11 feet, or, a board 12 feet long and 2 inches wide contains 2 feet, the *11* and the *2* being the 11- and the 2-inch figures of the outside-edge graduations.

9. For a practical illustration, suppose that it is required to find the contents of a board 14 feet long and 10 inches wide. Under the 12-inch mark on the outer edge of the square will be found the figure *14*, which represents the length. Follow the space in which the *14* is placed back to the row of figures under *10* on the graduations, where will be found the figures *11*|*8*, which is read 11$\frac{8}{12}$ feet, or 11 feet 8 inches, and is the contents of the board. In a like manner, if a board is 14 feet long and 16 inches wide, the result will be found, under the 16-inch mark, to be *18*|*8*, or 18 feet 8 inches. If the board is 2 inches or 3 inches thick, it will be necessary to multiply the contents taken from the scale by 2 or 3, respectively.

The contents of a stick of timber 11 feet long, 10 inches wide, and 8 inches thick is 73 feet 4 inches, board measure, and is found thus: Under the 12-inch mark is found *11*; by passing along to the left on the same line to a point below the graduation mark *10*, *9*|*2* is found, which is read 9 feet 2 inches, and is the contents of a board 11 feet long, 10 inches wide, and 1 inch thick. To find the contents of a stick of timber with the same dimensions, but 8 inches thick, all that is necessary is to multiply 9 feet 2 inches by 8 inches, which gives 73 feet 4 inches.

10. By combining figures, the contents of boards, planks, or timber of greater lengths than those shown on the scale can be calculated. Thus, for a board 20 feet long, double the figures in the 10-foot row, and if the board is 2 inches thick, multiply the result by 2. To find the contents of a board 25 feet long, add the figures in the 12- and 13-foot rows.

With the foregoing examples as a guide, it should be possible to work out any number of combinations and thus find the contents of a stick of any size. It should be remembered that this measure is calculated, as its name indicates, for **board measure**—abbreviated B. M.—which is the surface of a board 1 inch in thickness, 1 foot B. M. meaning a board 1 foot long, 1 foot wide, and 1 inch thick.

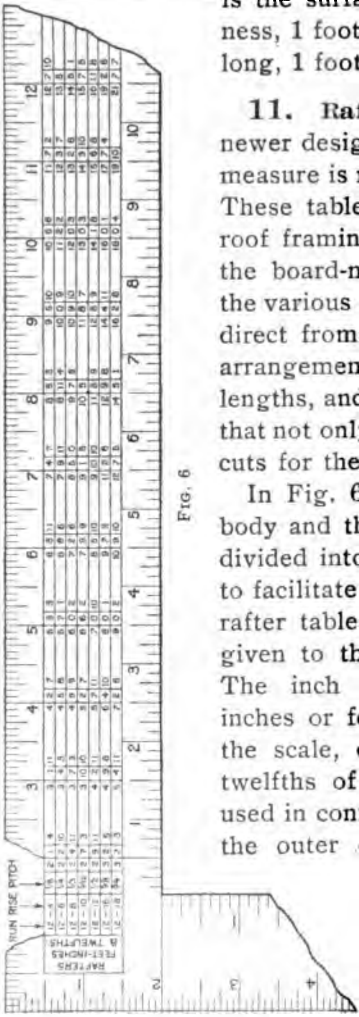


FIG. 6

11. Rafter Tables.—In some of the newer designs of steel squares, the board measure is replaced by the **rafter tables.** These tables are very convenient, and in roof framing are much more useful than the board-measure scale, as the cuts for the various members of a roof may be read direct from the scale. Fig. 6 shows one arrangement of the scale, giving the lengths, and Fig. 7 shows an arrangement that not only gives the lengths but also the cuts for the several members of the roof.

In Fig. 6, the outer edge of both the body and the tongue has the inches subdivided into *twelfths.* This subdivision is to facilitate measurements taken from the rafter table, as all the measurements are given to the nearest twelfth of an inch. The inch marks may represent either inches or feet, and the twelfth marks on the scale, either twelfths of an inch or twelfths of a foot. The rafter table is used in connection with the inch marks on the outer edge of the square. These figures represent one-half the span of the building, or the run of the rafter in feet or inches. The 6-inch graduation may be either 6 feet or 6 inches.

12. Run, Rise, and Pitch.—In the first column of the table, Fig. 6, at the heel of the square, the figures are all *12,* which may be used to indicate either 12 inches or 12 feet.

These figures represent the **run** of a rafter, which is the horizontal distance from the extreme end of the foot to a plumb-line hung from the ridge.

The figures in the second column represent the various *rises*. If 12 inches is used for the run, the various rises are read in inches, and if 12 feet is used for the run, the rises are read in feet. The **rise** is the vertical distance from the top of the ridge to the level of the plate.

The figures in the third column, expressed in fractions, represent the various pitches. The **pitch** is the proportion that the rise bears to the whole width of the building.

13. How to Use the Rafter Tables.—The three columns of figures just mentioned show that a rafter with a run of 12 and a rise of 4 has a $\frac{1}{6}$ pitch; with a run of 12 and a rise of 6, a $\frac{1}{4}$ pitch; and so on to the bottom of the columns. The span of a building with a run of 12 feet is 24 feet, and if the pitch is $\frac{1}{6}$, the rise will be $\frac{1}{6} \times 24 = 4$ feet.

To illustrate the use of the tables, a $\frac{1}{6}$-pitch roof having a run of 9 feet will have a span of 18 feet and a rise of $\frac{1}{6} \times 18 = 3$ feet. To find the length of a rafter for a roof of that width and pitch, look in the column under Pitch and find $\frac{1}{6}$; then follow the parallel ruling until the column of figures under the graduation marked *9* is reached. Here will be found the length of the rafter, which is *9*|*5*|*10*, or 9 feet $5\frac{10}{12}$ inches.

To find the length of a rafter for a building with a 24-foot span and $\frac{1}{2}$-pitch roof, proceed as follows: The run of the rafter will be 12 feet; then look in the column under Pitch for $\frac{1}{2}$, follow the parallel ruling from this point to the column under *12*, and the figures *16*|*11*|*8*, or 16 feet $11\frac{8}{12}$ inches, will indicate the length of rafter to be used.

14. When the run is expressed in inches, then, in the rafter table, read inches and twelfths instead of feet and inches. If, with a $\frac{3}{4}$-pitch roof the run is 10 feet 4 inches, add the rafter length for 10 feet to that of 4 inches. The rafter length for a 10-foot run and a $\frac{3}{4}$ pitch is 18 feet and $\frac{4}{12}$ inch; for 4 inches the length is $7\frac{3}{12}$ inches. Adding the two lengths gives for the total length of the rafter 18 feet $7\frac{7}{12}$ inches. The inches are obtained in the following manner: Under *4*, in the same line as $\frac{3}{4}$, is found the numbers *7 | 2 | 6*; *7* stands for inches, *2* for $\frac{2}{12}$ inch, and *6* for $\frac{6}{10}$ of $\frac{1}{12}$ inch. As $\frac{6}{10}$ is over $\frac{1}{2}$, it is read as $\frac{1}{12}$ more, thus making $7\frac{3}{12}$ inches for the length of the 4-inch run. In the column under *10*, calling the run 10 inches, the lengths for the several pitches, in inches, reading down the column, are $10\frac{7}{12}$, $11\frac{2}{12}$, 12, 13, $14\frac{2}{12}$, 16, and 18.

THE NICHOLS SQUARE

15. Fig. 7 shows a portion of the body of a steel square, known as the **Nichols square,** on which is a table giving the lengths of common rafters, hip, or valley, rafters, and jack-rafters; also, the cuts for the rafters and sheathing. The inch marks on the top edge are used, in connection with the table, to represent the rise per foot. The 6-inch mark means 6 inches rise for 12 inches run, and the columns of figures under the inch marks refer to the lengths and cuts pertaining to that particular rise.

16. The first line of figures on the Nichols square, Fig. 7, gives the length of the common rafter per foot of run, and is used in this way: It is required to find the length of the common rafters for a roof with a span of 16 feet and a rise of 10 inches per foot of run, which is equal to a $\frac{5}{12}$ pitch. The run of a rafter for a building 16 feet wide is 8 feet. Under *10* in the first line are the figures *15 | 62*, or 15.62 inches, which is the length of the common rafter for a 1-foot run; then, for an 8-foot run, multiply 15.62 by 8, which gives 124.96 inches, or 10 feet 4.96 inches, which is the length of the common rafters.

17. The second line of figures in Fig. 7 gives the length of hip or valley rafters per foot of run. To find the length of hip or valley rafters having the same dimensions as the common rafters just mentioned, that is, an 8-foot span and a 10-inch rise per foot, look in the column headed *10*, and

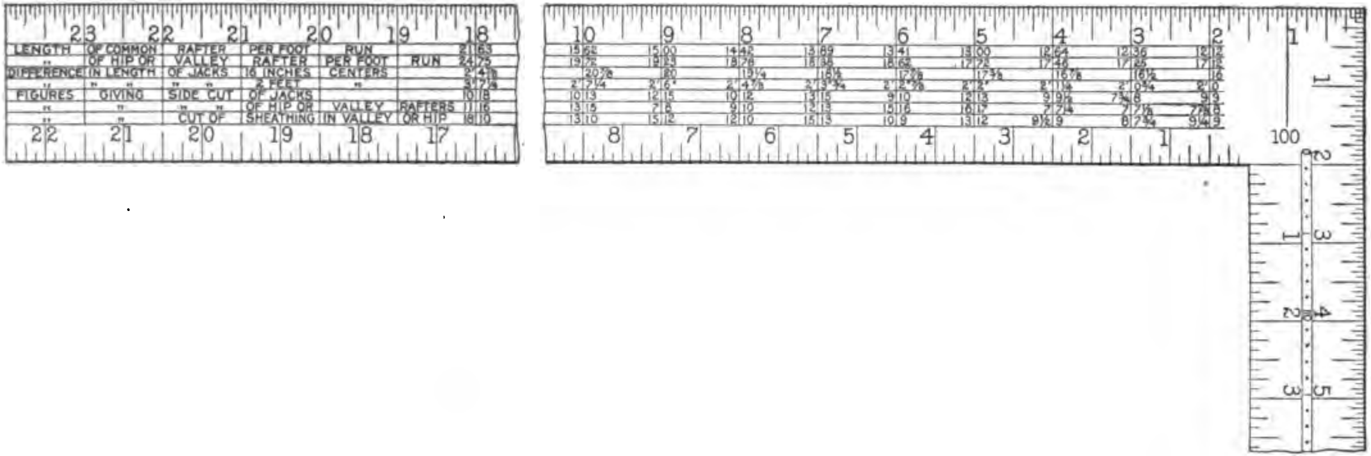

LENGTH OF COMMON RAFTER PER FOOT RUN
" OF HIP OR VALLEY RAFTER PER FOOT RUN
DIFFERENCE IN LENGTH OF JACKS 16 INCHES CENTERS
" " " " " 2 FEET "
FIGURES GIVING SIDE CUT OF JACKS
" " " " OF HIP OR VALLEY RAFTERS
" " CUT OF SHEATHING IN VALLEY OR HIP
100

FIG. 7

directly under *15|62* will be found the figures *19|72*, or 19.72 inches. Then, multiplying these figures by the run of the common rafter, or 8 feet, will give the desired length. Thus, 19.72 × 8 = 157.76 inches, or 13 feet 1.76 inches.

18. The third line of figures gives the length of the first jack-rafter and the difference between the length of the other jack-rafters when spaced 16 inches on centers. For example, the first jack-rafter on a hip in the foregoing example will be $20\frac{7}{8}$ inches, the figures being obtained from the third line in the column headed *10*. The length of the second jack-rafter will be $20\frac{7}{8} + 20\frac{7}{8} = 41\frac{6}{8}$ inches, and of the third jack-rafter, $41\frac{6}{8} + 20\frac{7}{8} = 62\frac{5}{8}$ inches.

19. The fourth line in Fig. 7 gives the length of jack-rafters placed 2 feet on centers, and is used in the same manner as the third row. If placed on 2-foot centers, the first jack-rafter will be 2 feet $7\frac{1}{4}$ inches long.

20. The fifth line of figures in Fig. 7 gives the side cuts of jack-rafters that fit against hip or valley rafters. The side cut for jack-rafters in the foregoing case is 10 inches on the body and 13 inches on the tongue of the square, the tongue giving the cut. To obtain these figures, look at the fifth line under *10*, and there will be found *10|13*; the first figure *10* has reference to the distance from the heel of the square on the body, which is 10 inches, and the second figure *13* has reference to the distance from the heel on the tongue, which is 13 inches.

21. The sixth line of figures in Fig. 7 gives the side cuts of hip or valley rafter against the ridge board, or deck, and is used in the same manner as the figures that give the side cuts of jack-rafters. The figures *13|15*, in the column headed *10*, mean 13 inches on the body and 15 inches on the tongue of a square, the tongue giving the cut.

22. The seventh line of figures in Fig. 7 gives the cuts of sheathing and shingles in valleys or on hips. In the column headed *10* will be found the figures *13|10*. By placing the square on the material to be cut so that the figures *13* on the body and *10* on the tongue will intersect one edge, and cutting along the tongue, the correct cut for sheathing or shingles will be obtained.

23. The jack-rafter marks on the Nichols square, Fig. 7, will also give a number of other cuts useful in roof framing. The figures on the square giving side cuts of jack-rafters will also give the miter cuts for moldings in the valley at the junction of two gables, and will give the miter cuts for gable moldings where they intersect with level moldings at the end of a building.

The figures giving cuts of sheathing for valleys or hips will give cuts for mitering level planchers with gable planchers, also the miter cuts where two gable planchers intersect, and the cut for a plancher on the gable end.

In addition to the rafter tables, the Nichols square illustrated in Fig. 7 also has the brace scale, the octagon scale, and 1 inch subdivided into hundredths.

ORDINARY STEEL SQUARE

24. While the tables and scales described in the preceding articles are very useful and convenient and may be relied on as being correct, there is not a single framing problem likely to arise in practice that cannot be solved by means of an ordinary steel square with only the graduations marked on the edges, provided the graduations are true and the body and tongue are at right angles to each other. The importance of having a square true will be made clear in the following pages.

25. Testing a Square.—In order to test a square to see that the body and tongue are at right angles, take a board 12 inches or more in width and at least 4 feet in length, surface it on one side, and true up one edge so as to be perfectly straight. Place the square as shown at *a*, Fig. 8, and mark the board along the tongue both on the outer and on the inner edges; then reverse the square as shown at *b*, and if the outer edge of the tongue coincides with the mark made on the outer edge of the tongue in *a* it is proof that the inner edge of the body is at right angles to the outer edge of the tongue. If, by moving the square *b* over to the right until the outer edge of the tongue comes to the mark made along the inner edge of the tongue in *a*, the edge and the mark coincide, it is proof that the inner edge of the tongue is at right angles to the inner edge of the body, and also that the two edges on the tongue are parallel.

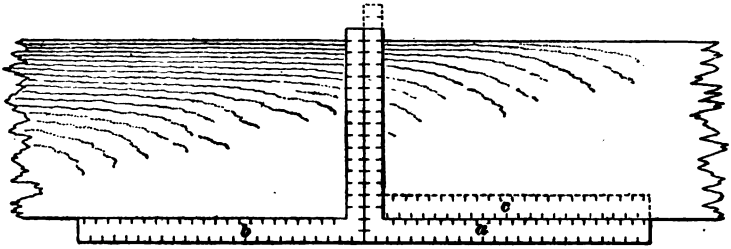


FIG. 8

26. In a like manner it can be shown that the outer edge of the body is at right angles to the tongue or that the two edges of the body are parallel. To do so, move the square *a* until the outer edge of the body coincides with the straight edge of the board, as shown at *c*, Fig. 8. Then, if this edge is at right angles to the tongue, the tongue will coincide with the marks, provided, of course, that the square in the first case was true with regard to the edges. If any of the edges are not true, they may be made so by filing or

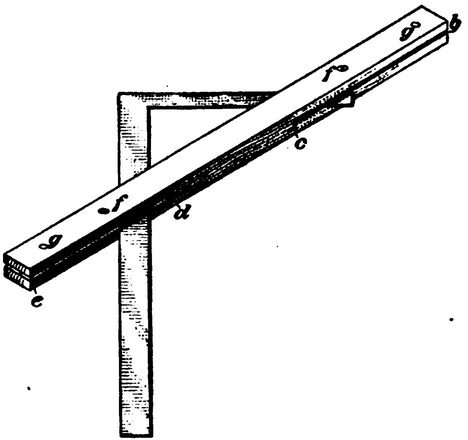


FIG. 9

grinding the tongue or the body until at right angles, using the marks on the board as a gauge, or templet.

27. The Fence.—In Fig. 9 is shown an adjustable fence with the square set. A **fence** consists of a strip of hardwood—cherry or black walnut being preferable—about 2 inches wide, 1½ inches thick, and from 2½ to 2⅝ feet long. Saw kerfs *bc* and *de* are cut in from each end, leaving from 6 to 8 inches of solid wood in the center, as shown at *cd*. Two holes *f* and *g* are bored through each end, and two screws are inserted, as shown at *f*, to bind the fence on the square.

Fig. 10 shows the method of using the fence. The body and tongue are clamped fast at the run *k*, *j* and rise *j*, *h*; then, if the fence and square are applied to a rafter the correct number of times, the length and the top and bottom cuts for the rafter will be obtained. The letters *g* and *d* show the foot-cut; *n*, *o*, *p*, *q*, *k*, *h*, and *l*, the marks used to obtain the length of the rafter; and *l* and *m*, the top cut.

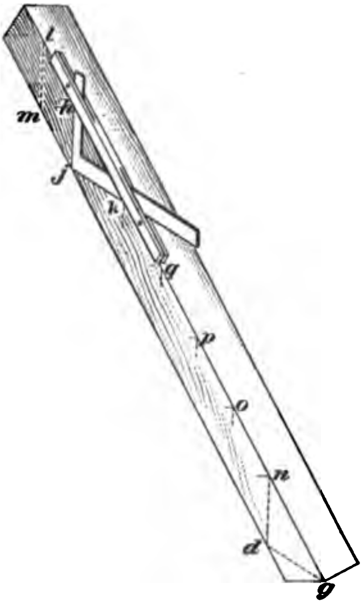


FIG. 10

APPLICATION OF THE SQUARE

PRACTICAL METHODS

28. While the octagon scale, diagonal scale, brace scale, and board measure on a square are very convenient, they are not absolutely necessary, and after becoming thoroughly conversant with the principles underlying the use of the steel square, the scales will be found of little use. The same might also be said of the rafter tables. There are many other ways of obtaining the information contained in the scales and tables on a square, and some of these methods will now be explained.

29. Framing an Octagonal Post From a Square Timber.—In Fig. 11 is shown an end view of a stick of timber 10 inches square that is to be marked so that an octagonal post can be cut from it. To find the required lines, lay the square on the two diagonals and mark the lines $a\,c$ and $b\,d$. Measure the distance $b\,e$, which is one-half $b\,d$, and lay off this distance on $b\,a$ and $b\,c$, marking the points a'' and c'; these two points will then be two corners of the octagon. In the same manner, lay off the distance $b\,e$ from a, d, and c, marking the points b'' and d', a' and c'', and d'' and b'. Draw lines $a''\,a'$, $d'\,d''$, $c''\,c'$, and $b'\,b''$, and thus complete the octagon. This method may also be employed in laying out octagons on large plans or on the ground.

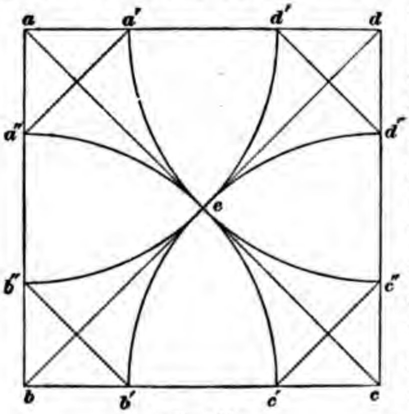


FIG. 11

30. Another method of finding the points for an octagon on a square stick of timber is illustrated in Fig. 12, where *a b c d* represents the end section of a piece of square timber.

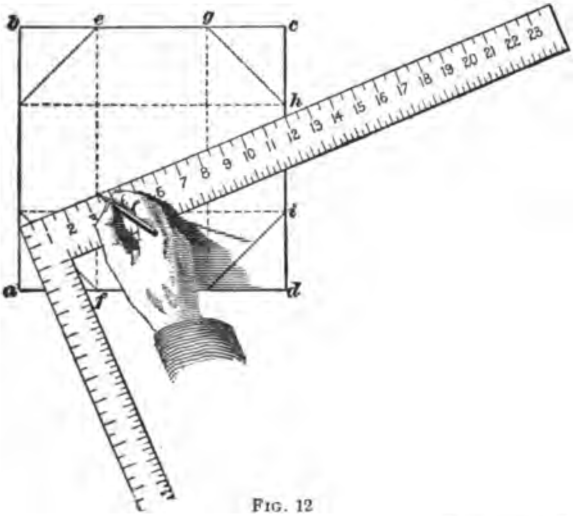


FIG. 12

Lay the steel square on the timber in such a way that any twenty-four divisions on the square will be contained between two parallel sides, and then mark off seven divisions from both sides. In the figure, the heel of the square is placed at one side and the 12-inch mark at the other, making twenty-four half-inch divisions. On one side, the seven divisions will therefore come at the $3\frac{1}{2}$-inch mark, and on the other at $12 - 3\frac{1}{2} = 8\frac{1}{2}$ inches, or the $8\frac{1}{2}$-inch mark. If the 6-inch mark is used for a diagonal width, then each

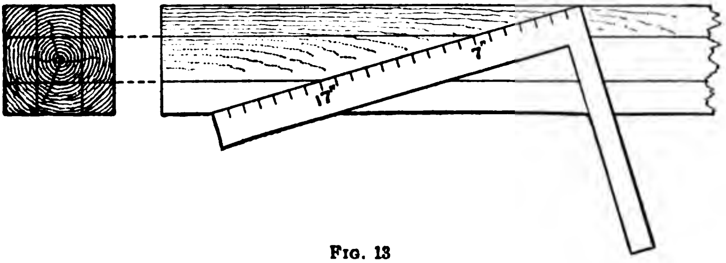
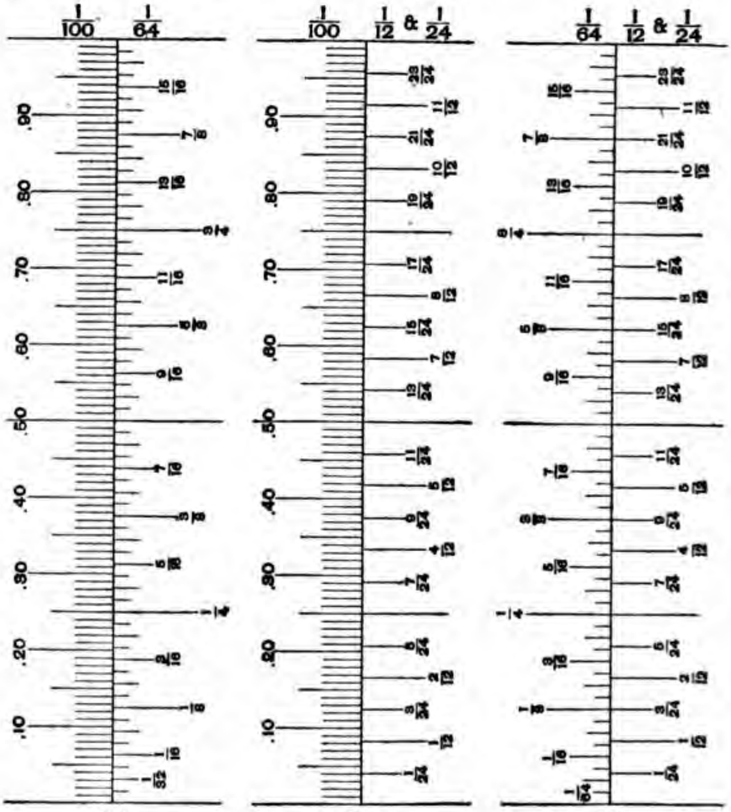


FIG. 13

division will be equal to $\frac{1}{4}$ inch, and the marks will come at $1\frac{3}{4}$ and $4\frac{1}{4}$ inches, respectively.

Fig. 13 shows the same principle applied to the side of the timber. The full length of the body of the square is used—thus making each division 1 inch—and the gauge marks come at 7 and 17 inches, respectively.



(a) (b) (c)

FIG. 14

31. Decimal Scale.—One one-hundredths ($\frac{1}{100}$, or .01) inch is a very small division, and one that is practically impossible to use on the edge of a square. The decimal division of the inch, however, is very convenient for calculations,

TABLE I

DECIMALS OF AN INCH FOR EACH 64TH AND 24TH

Decimal	Fraction	32ds	64ths	12ths	24ths	Decimal	Fraction	32ds	64ths	12ths	24ths
.0156			1			.5156			33		
.0312		1	2			.5312		17	34		
.0417					1	.5417					13
.0469			3			.5469			35		
.0625	1/16	2	4			.5625	9/16	18	36		
.0781			5			.5781			37		
.0833				1	2	.5833				7	14
.0937		3	6			.5937		19	38		
.1094			7			.6094			39		
.125	1/8	4	8		3	.625	5/8	20	40		15
.1406			9			.6406			41		
.1562		5	10			.6562		21	42		
.1667				2	4	.6667				8	16
.1719			11			.6719			43		
.1875	3/16	6	12			.6875	11/16	22	44		
.2031			13			.7031			45		
.2083					5	.7083					17
.2187		7	14			.7187		23	46		
.2344			15			.7344			47		
.25	1/4	8	16	3	6	.75	3/4	24	48	9	18
.2656			17			.7656			49		
.2812		9	18			.7812		25	50		
.2917					7	.7917					19
.2969			19			.7969			51		
.3125	5/16	10	20			.8125	13/16	26	52		
.3281			21			.8281			53		
.3333				4	8	.8333				10	20
.3437		11	22			.8437		27	54		
.3594			23			.8594			55		
.375	3/8	12	24		9	.875	7/8	28	56		21
.3906			25			.8906			57		
.4062		13	26			.9062		29	58		
.4167				5	10	.9167				11	22
.4219			27			.9219			59		
.4375	7/16	14	28			.9375	15/16	30	60		
.4531			29			.9531			61		
.4583					11	.9583					23
.4687		15	30			.9687		31	62		
.4844			31			.9844			63		
.5	1/2	16	32	6	12	1.0000	1	32	64	12	24

and if understood better by the average mechanic would no doubt be used more in the graduations of scales. Probably the best way to fully comprehend the value of $\frac{1}{100}$ inch would be to compare it by illustration with the twelfth and sixty-fourth divisions. In Fig. 14 (*a*), the decimal divisions of an inch are compared with the sixty-fourth divisions, at (*b*) they are compared with the twelfth and twenty-fourth divisions, while at (*c*) the sixty-fourth divisions are compared with the twelfth and twenty-fourth divisions.

In Fig. 14, the inch is enlarged to four times its actual size, thus making the subdivisions easy to read. As an example, take eighty-seven one-hundredths inch (.87 inch), and it is found to equal $\frac{7}{8}$, or $\frac{21}{24}$, inch. Or, suppose a measurement of .39 inch is given; by referring to the $\frac{1}{100}$ scale, it will be found that this measurement is equal to $\frac{25}{64}$ inch. The eye catches the figures on the scale more quickly than those in a table.

The comparison of the several divisions of the inch are also given in Table I.

LAYING OUT BRACES

32. The length of braces may be obtained with a steel square without the aid of a brace scale. While the brace scale gives only a very few lengths—and these are generally of equal runs and rises—the following methods will give the length of any brace with equal run and rise, also the lengths of braces with unequal run and rise. The length of a brace is equal to the hypotenuse of a right triangle. If the run and the rise are equal, as in Fig. 15, all that is necessary is to multiply the run by the constant 1.4142. This method is really quicker than measuring along the tongue and body of the square. The constant 1.4142 is equal to the

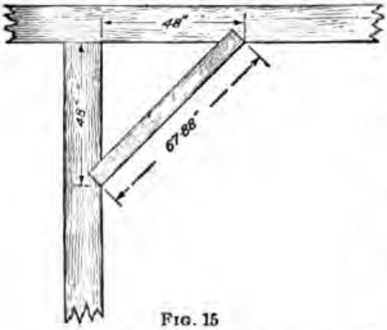


Fig. 15

diagonal from 12 inches on the tongue to 12 inches on the body. Expressed in inches, the diagonal is 1.4142 × 12 = 16.9704.

The constant 1.4142 plays a very important part in roof framing. For instance, if the diagonal of 12 inches and 12 inches is 1.4142 feet, or 16.97 + inches, the diagonal of any other equal distances at right angles to each other may be found by multiplying one of the distances by the constant 1.4142.

Example.—The rise on a post is 4 feet and the run on the girder is 4 feet. What will be the length of the brace?

Solution.—The length of the brace is found by multiplying one of the distances by the constant 1.4142. Thus, 1.4142 × 4 ft. = 5.6568 ft. Reducing this to inches it becomes 5.6568 × 12 = 67.88 in. Ans.

This same result may be obtained by the following methods: 1.4142 × 48 in. = 67.88 in.; or, 16.97 × 4 ft. = 67.88 in.; or, 16.97 × 48 in. = 814.56, then, 814.56 ÷ 12 = 67.88 in. It will thus be seen that feet or inches may be used, either in the diagonal or in the run or rise.

33. Fig. 16 shows a method of obtaining the length of a brace by measuring the diagonal between the run and the rise. The length of a brace with an equal run and rise of 65 inches is required. As 65 is beyond the limits of the square, it will be necessary to use multiples of 65 or multiples of a part of 65. Take 60 and 5; the 5 is within the limits of the square, and the 60 may be brought within the limits by dividing by 4; thus, 60 ÷ 4 = 15. Then, to obtain the length, measure the diagonal, or *bridge measure*, between

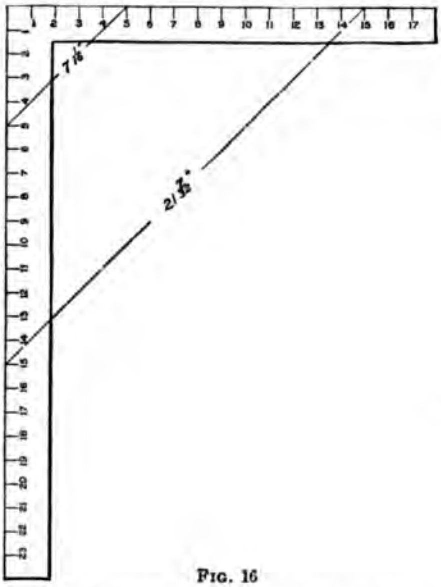


Fig. 16

15 inches on the tongue and 15 inches on the body of the square. Multiply this distance by 4, because $4 \times 15 = 60$. Now, measure the diagonal between 5 inches on the tongue and 5 inches on the body of the square, and add this distance to the length of the diagonal of 15 and 15 multiplied by 4. The diagonal of 15 and 15 is found to be $21\frac{7}{32}$ inches, and that of 5 and 5 is $7\frac{1}{16}$ inches; $21\frac{7}{32} \times 4 = 84\frac{28}{32}$, and $84\frac{28}{32} + 7\frac{1}{16} = 91\frac{15}{16}$ inches, which is the length of the brace. These figures may be proved by multiplying 1.4142 by 65 inches.

34. The length of the foregoing brace may also be found by taking the run in feet; 65 inches is equal to 5 feet 5 inches, or $5\frac{5}{12}$ feet. By measuring the diagonal from $5\frac{5}{12}$ inches on the tongue to $5\frac{5}{12}$ inches on the body of the square, and calling the measurement feet, it is found to be $7\frac{8}{12}$ feet, or 92 inches long; but 92 inches is $\frac{1}{16}$ inch longer than in the first case. The diagonal of $5\frac{5}{12}$ and $5\frac{5}{12}$ is not exactly $7\frac{8}{12}$ inches, however, but is near enough for most practical purposes.

Nearly all the better makes of squares have one edge of the body and one edge of the tongue graduated into twelfths of an inch and by reading the inches as feet, the twelfths of an inch will represent inches; thus, half of a twelfth would equal $\frac{1}{2}$ inch. If the run and rise were $8\frac{1}{2}$ feet, the length of the brace could be found by taking $8\frac{6}{12}$ inches on the body and $8\frac{6}{12}$ inches on the tongue and measuring the diagonal, which would be found to be 12 inches and $\frac{1}{4}$ of $\frac{1}{12}$ inch long. Calling the inches feet, the length of the brace would be 12 feet and $\frac{1}{4}$ inch.

In braces of equal run and rise, the top and the bottom cuts are at 45°, provided that the brace is between two timbers at right angles to each other. The cuts are obtained by taking any equal numbers on the body and tongue of the square.

35. Another method of finding the length of a brace is to take the length of the run on the tongue and the length of the rise on the body of the square and apply the square to the brace the same number of times as there are feet in the run. When using the square in this manner, however, the 12-inch mark is used on the tongue or body for the run.

Fig. 17 shows a brace between a post and a beam. The run and the rise are each 3 feet 6 inches. It will be observed that the body of the square gives the line for the cut along the post, and that the tongue of the square gives the cut along the beam.

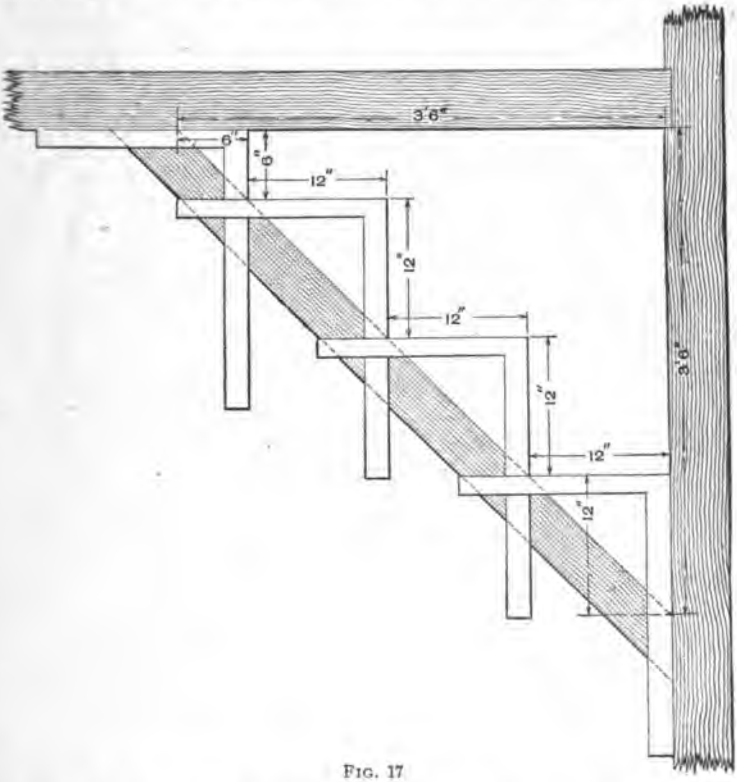


FIG. 17

36. Fig. 18 shows a brace in which the run is less than the rise; consequently, the brace does not form an angle of 45° with the post. The length may be found by multiplying the diagonal, or bridge measure, between 12 and 9 by the rise, because the brace rises 12 inches for every 9-inch run. The length may also be found by applying the square as shown in Fig. 17.

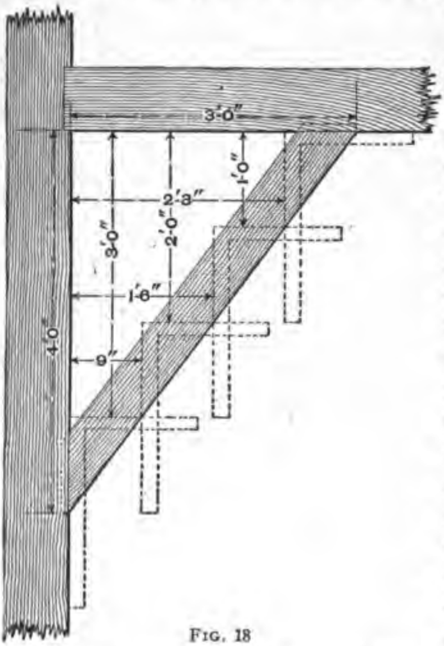


Fig. 18

In the brace shown in Fig. 18, the rise is 4 feet and the run is 3 feet. By taking 12 inches on the body and 9 inches on the tongue and applying the square four times, the length of the brace will be found. The body of the square gives the cut to fit against the post, and the tongue of the square gives the cut to fit against the beams. By measuring from the 4-inch mark on the body to the 3-inch mark on the tongue, and calling the inches feet, it will be found that the brace is 5 feet long; or, again, by measuring from 12 inches on the body to 9 inches on the tongue and multiplying the distance by 4, the length of the brace will be in inches. The bridge measure of 12 and 9 inches is 15 inches, and 15 inches × 4 = 60 inches, or 5 feet.

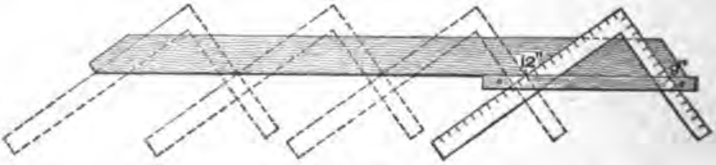


Fig. 19

37. Fig. 19 shows the way to apply a square to get the length and the top and bottom cuts of a brace.

38. Fig. 20 shows a method of getting the length and cuts in cross-bracing. In this illustration, the top and bottom timbers are 12 feet apart, and the distance between centers of the braces at both top and bottom is 10 feet. By calling 10 feet the run and 12 feet the rise, and using these distances on the tongue and body of the square, it will be readily seen that applying the square twelve times will give not only the run and rise, but also the length of each brace. It should be remembered, however, in using the figures on the square, that the 10 inches on the tongue and the 12 inches on the body represent the run and the rise on a scale of 1 inch to 12 inches.

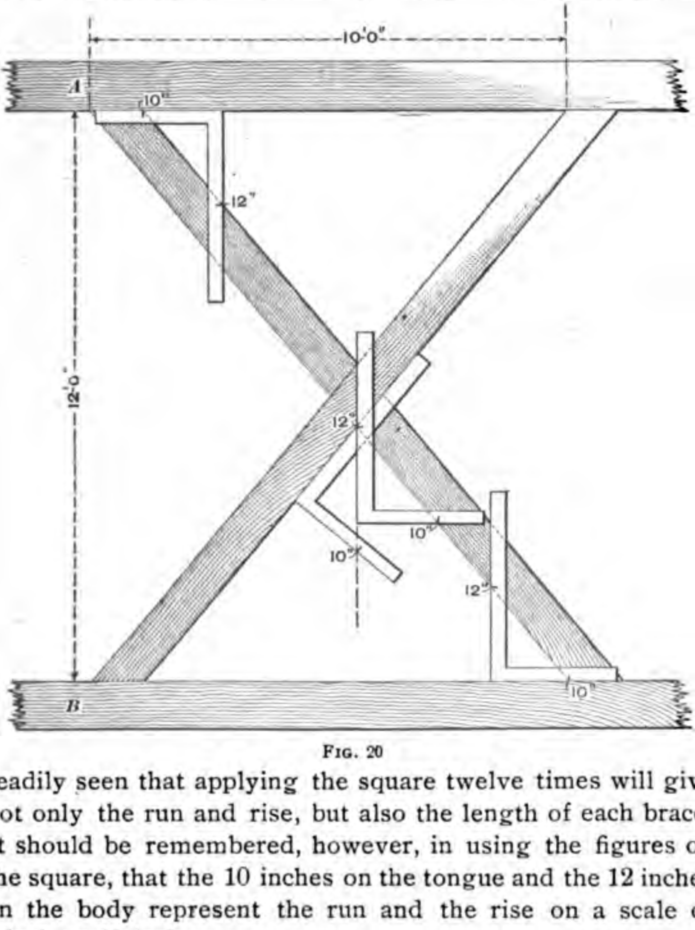


FIG. 20

The bridge measure of 10 and 12 inches is 15.62 inches, and 12 × 15.62 = 187.44 inches, which is the length of the brace. If, instead of calling the marks on the body and the tongue inches, they are designated as feet, the bridge measure will be 15.62 feet, and 15.62 feet is equal to 15 feet 7.44 inches, or 187.44 inches. It will be observed that the tongue of the square will give the top and bottom cuts, and the body of the square will give the cut at the center to frame the two braces together.

39. Board Measure.—The number of feet, board measure, may be found by the aid of the square without referring to the board-measure scale. When a number of boards of the same length, but having different widths, are

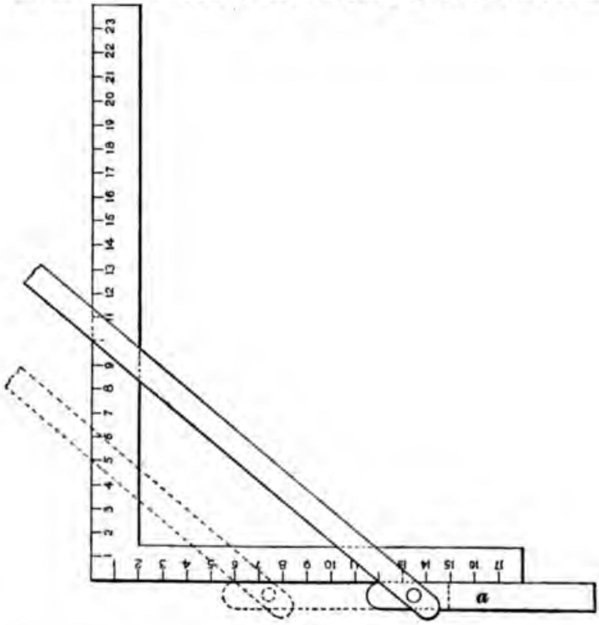


FIG. 21

to be measured, the following method will probably save time, especially if a bevel instrument with a long blade is used.

At *a*, Fig. 21, is shown the application of the bevel to the square. The blade of the bevel is set at the 12-inch mark on the tongue of the square and at the number corresponding to the length of the board on the body of the square. Then, to find the number of feet, board measure, in the board, move the bevel so that the blade will intersect on the tongue the number equal to the width of the board. The bevel will then indicate on the body of the square the number of feet in the board.

In Fig. 21, the bevel is first set at *12* and *10*, the *10* being the length of the board in feet. The bevel is then moved along the tongue of the square to *6*, which is the width of the board in inches. When in this position the blade of the bevel rests on the body of the square at *5*, which is the contents of the board in square feet.

If the board were 16 feet long, 7 inches wide, and 2 inches thick, the bevel would be set at 12 inches and 16 inches, then moved to 7 inches on the tongue, and the bevel would indicate the contents of a board 1 inch thick, which would be $9\frac{4}{12}$ feet. This quantity must then be multiplied by 2, because the board is 2 inches thick. The product will be $18\frac{8}{12}$ feet, which is the contents of the board.

LAYING OUT POLYGONS

40. Although the steel square is particularly adapted for roof framing and is probably used more for that kind of work than for any other purpose, there are a great many other uses for the instrument. The mechanic that thoroughly understands the principle of the steel square will continually find new problems that can be solved with greater ease by the use of this instrument than by any other method. Therefore, before taking up the subject of roof construction, a few of the uses to which the square may be put will be explained.

41. **Classification of Polygons.**— A **polygon** is a plane figure bounded by straight lines. The bounding lines are called the **sides**, and the length of the broken line that bounds the figure is called the **perimeter** of the polygon. A **regular polygon** is one in which all the sides and all the angles are equal.

Polygons are classified according to the number of their sides: A polygon of three sides is called **a triangle;** one of four sides, a **quadrilateral;** one of five sides, a **pentagon;** one of six sides, a **hexagon;** one of seven sides, a **heptagon;** one of eight sides, an **octagon;** one of nine sides, a **nonogon;** one of ten sides, a **decagon;** one of eleven sides, an **undecagon;** and one of twelve sides, a **dodecagon.**

42. Laying Out an Equilateral Triangle.—In Fig. 22 is shown a method of finding the angle of the sides and also the miter angle of a regular polygon of three sides. A regular polygon of three sides is an **equilateral triangle,** and is consequently **equiangular,** that is, all sides are equal in length and the angles contain the same number of degrees.

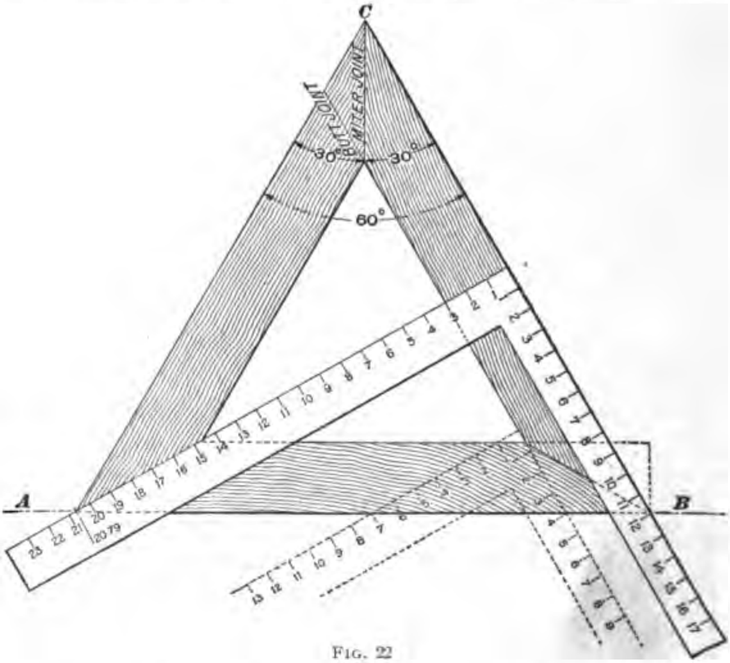


FIG. 22

In the illustration, *A B* represents the line on which the triangle is to be formed. Place the square so that 12 inches on the tongue and 20.79 inches on the body are over the line *A B*; then, the tongue will give the direction of one side of the triangle. By reversing the square so that the 12 inches is at *A* and the 20.79 inches is at *B*, the other side of the triangle may be drawn. The intersection of these two lines at *C* completes the triangle.

43. If a frame is to be constructed, the body of the square will give the direction to cut for a miter joint.

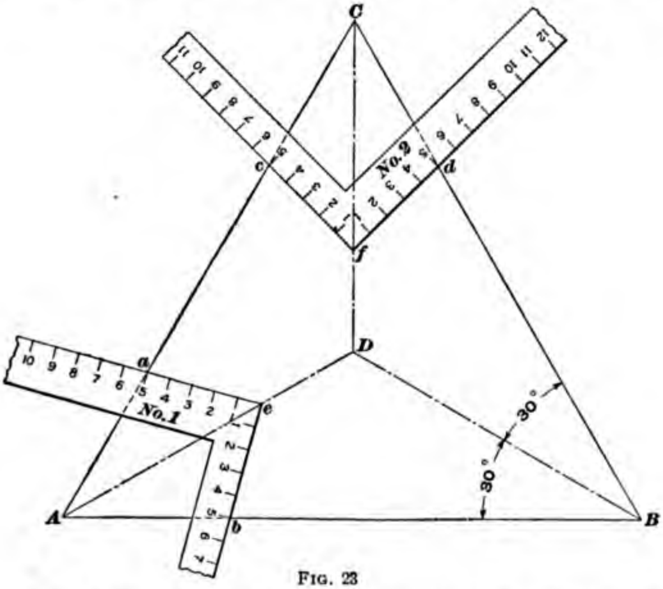


FIG. 23

If a butt joint is required, however, the cut will be along the tongue, using the same figures on the square. The miter joint makes an angle of 30° with the sides, while the butt joint is parallel with the sides. The direction of these cuts can also be found by using 7 inches on the body and 4 inches on the tongue. While these figures are not absolutely correct, they are close enough for all practical purposes. They may be proved by using the proportion 20.79 : 12 = 7 : 4.04. It will therefore be seen that 4 inches is .04, or about $\frac{1}{32}$, inch too short.

44. Locating the Center of a Triangle.—Fig. 23 shows one method of finding the center of a triangle, also a method of bisecting any angle. This same method may be used to find the center of any regular polygon. *A B C* represents the triangle. Make *A a* equal to *A b*, and place the square as shown at *No. 1;* that is, with equal divisions resting on the lines *A C* and *A B*, at *a* and *b*. Make a mark at the heel of the square as at *e*, and from *A* through *e* draw a line of indefinite length. From the angle at *C*, lay off *C c* and *C d* equal to each other. Place the square, as shown, at *No.* 2, and make a mark at *f*. From *C*, through *f*, draw a line intersecting the other line *A D*; then, *D* will be the center of the triangle. To prove the work, the same operation may be repeated at angle *B*. Then, if the line *B D* intersects the other two lines at *D*, the operations at *A* and *C* have been performed correctly.

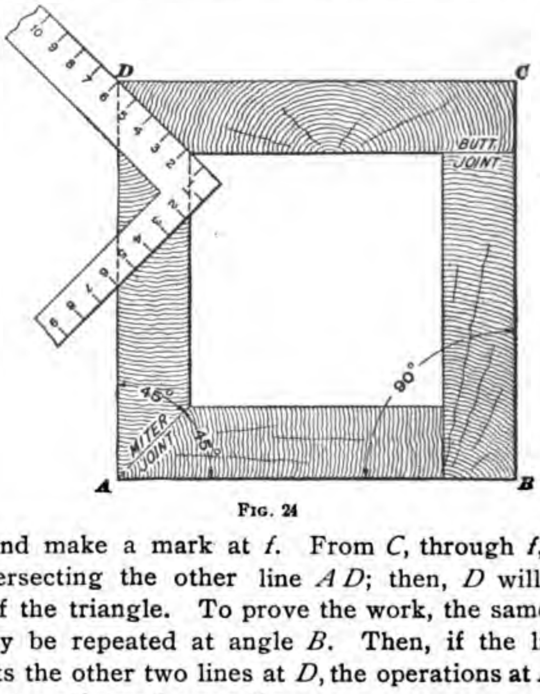


Fig. 24

The lines *A D*, *B D*, and *C D* bisect the angles *A*, *B*, and *C*, respectively. In the illustration, the 5-inch mark is used on both the body and the tongue of the square. Any other figures may be used, however, provided they are at equal distances from the heel of the square.

45. Laying Out a Regular Quadrilateral Polygon, or Square.—Fig. 24 represents a square frame. The corners at *A* and *D* are made with miter joints, and those at *B* and *C*, with butt joints. The miter joint shown is the true miter, because the pieces are cut off at an angle of 45°. Common usage, however, has made it customary to speak of a miter joint when the pieces come together at angles other than 45°.

In order to find the direction of the cut for a 45° miter joint, use any equal numbers on the body and on the tongue, and cut along either edge of the square. In the illustration, 6 inches and 6 inches have been used. It will be observed that the body coincides with the direction of the miter at *D*, and that the tongue is parallel with the miter at *A*. The butt joint is a square cut.

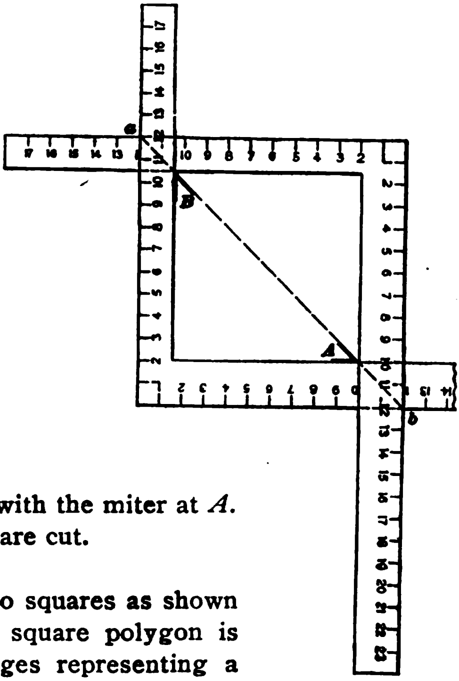


FIG. 25

46. By placing two squares as shown in Fig. 25, a regular square polygon is formed, the outer edges representing a square with 12-inch sides. Now, if a line *a b* is drawn diagonally from 12 inches to 12 inches, on measurement it will be found to be 16.97 inches long, but for most practical purposes, 17 inches will be found sufficiently exact. The constant, 17 inches, plays a very important part in roof framing. By assuming that the 12 divisions on a square represent feet instead of inches, the 17 will also represent feet. Now, assuming that the *12* on the body represents the *run* of a rafter, and that the *12* on the tongue represents the *rise*, then the 17 will represent the length of the rafter. This operation will also give the cuts of the rafter at the plates and ridge. Bevel *A* will give the correct angle of cut at the plate, and bevel *B* will give the correct cut at the ridge.

47. Laying Out a Regular Pentagon, or Five-Sided Polygon.—In Fig. 26, *A B C D E* represents the outside of a pentagon. To construct the pentagon, draw a line *A b*, and place the square on this line, as shown, with 11 inches on the body and 8 inches on the tongue. Mark along the tongue *A E*; then reverse the position of the square, as shown at *A B b*, and mark along the tongue *A B*. The two sides of the pentagon, or at least the direction of the two sides, will then be determined. To find the direction of the side *B C*, erect a perpendicular to the line *A E* at *4*, or the center of the line *A E*; then place the square as shown by the dotted lines. In the same manner, the direction of the other sides may be found; or, the direction and lengths may be found by the use of compasses.

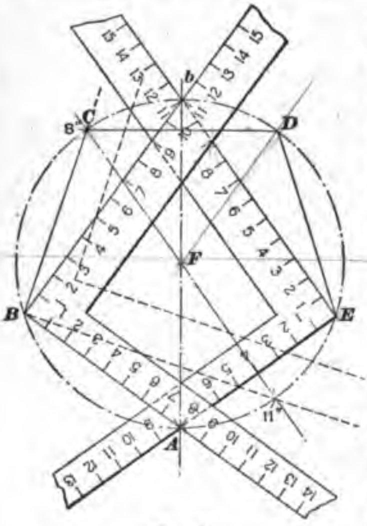


FIG. 26

48. Fig. 27 shows the method of using a square to find the miter and butt joints of a pentagon. The same figures on the square that gave the directions of the sides in Fig. 26, that is, 11 inches and 8 inches, will also give the miter cut, the cut being along the 8-inch side. For the butt joint, take 12 inches and 3.9 inches, and cut on the 3.9 inches side.

49. Laying Out a Regular Hexagon, or Six-Sided Polygon.—The method of finding the direction of the sides of a regular hexagon is the same as that just described for a pentagon. The figures on a square to use for finding the sides of a hexagon are 12 inches and 6.93 inches, the figure last mentioned giving the direction.

In Fig. 28, *A B C D E F* represents the outline of a hexagon. At *A*, *B*, and *C* are shown miter joints, and at *D*, *E*, and *F*, butt joints. Take 12 inches on the body and 6.93 on the

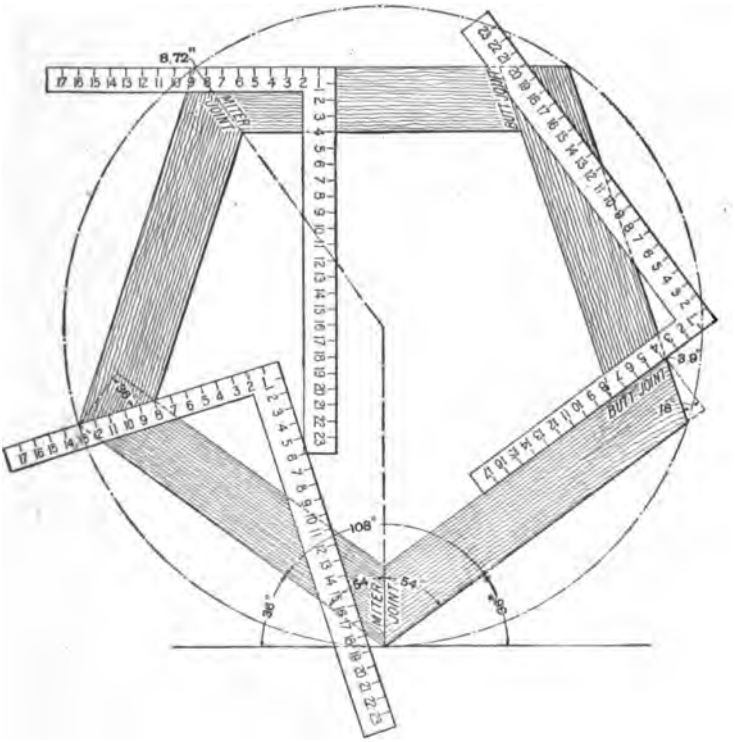


FIG. 27

tongue of the square, and mark along the tongue for both the miter and the butt joints. The whole numbers on the square that will give the hexagon cuts are 7 and 4, and the proportion 12 : 6.93 = 7 : 4.04 will show how nearly correct these figures are. It will be seen from this proportion that if 7 and 4 are used, the 4 is short by .04, or about $\frac{1}{32}$, inch. While this difference is very little for one cut, it should be remembered that as the number of sides increase, the error is multiplied by twice the number of sides. The polygon in question will have twelve cuts, and the difference for each cut, if 7 and 4 are used, will be 15′, or ¼°, and for twelve cuts it will be 12 × 15′ = 180′, or 3°. Therefore, instead of the sum of the interior angles of the hexagon being equal to 720°,

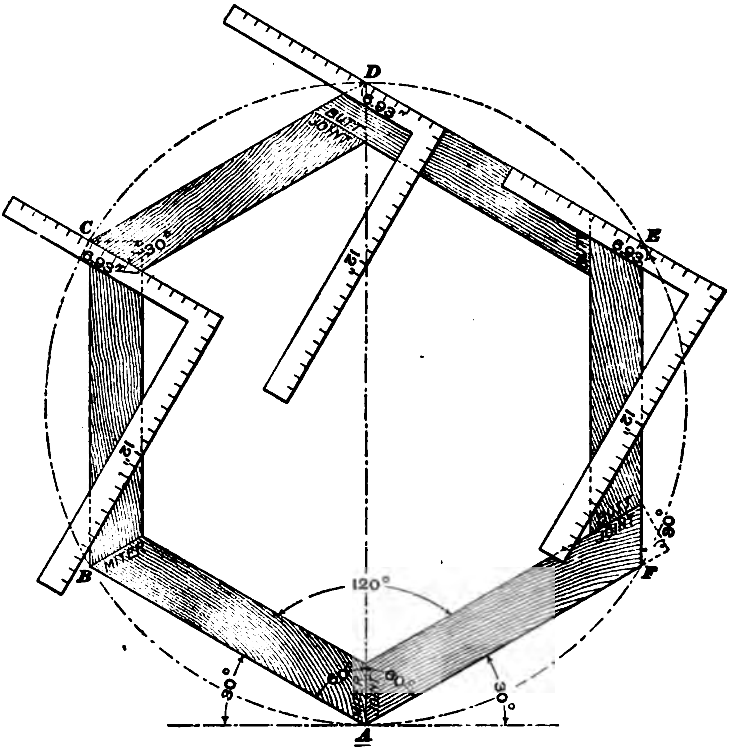


FIG. 28

it will be equal to 720° – 3° = 717°. Or, again, each angle of the hexagon is equal to 120° – 30′, or ½°, which is 119½°.

50. Laying Out a Regular Heptagon, or Seven-Sided Polygon.—The same method employed for finding the direction of the sides in a pentagon or hexagon may be used for laying out a heptagon.

In Fig. 29, *ABCDEFG* represents the outside of a regular heptagon. The angles at *A*, *B*, *C*, and *D* are miter joints, and those at *E*, *F*, and *G* are butt joints. The figures on the square that give the cuts for the miter joint are *12* and *5.78*, the cut being on the 5.78-inch side. For the butt joint, take *12* and *9.57*, and the 9.57-inch side gives the cut.

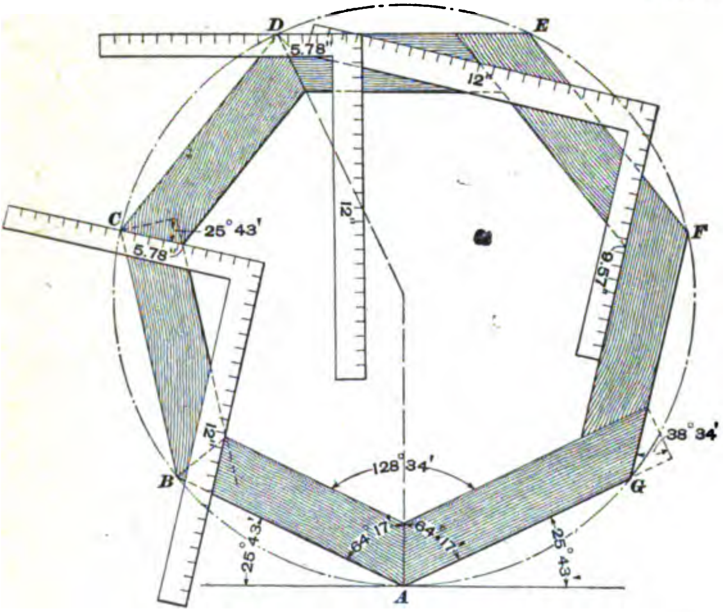


FIG. 29

The figures on the square that give the miter cuts for the heptagon are *14½* and *7*. These figures are very close, as will be seen by the proportion 12 : 5.78 = 14.5 : 6.984.

51. Laying Out a Regular Octagon, or Eight-Sided Polygon.—In Fig. 30, *ABCDEFGH* represents the outside lines of an octagon. The figures on the square that give the miter cuts are *12* and *4.97*, the cutting to be done on 4.97-inch side. The figures to use for butt joints are *12* and *12*, or any equal distances from the heel on the tongue and the body of the square. In other words, the cut for a butt joint is a square miter.

The whole numbers that give the octagon miter are *17* and 7. These figures are very nearly correct, as will be seen by taking 12 and 4.97, which are absolutely correct, and making the proportion 12 : 4.97 = 17 : 7.04. That is, if 17 is used, 7.04 will be correct. The difference in this case is not so great as would be supposed. To find just what the error will be, take the proportion 17 : 7 = 12 : 4.94 and compare it with the correct figures, which are 12 and 4.97. Thus, the actual error due to using 17 and 7, is .03 inch, which is equal to 6′ in each cut, or 12′ in each joint; and for the eight joints, will be 96′, or 1° 36′. It might be well to mention here that these comparisons are stated in this manner more to show the care that should be taken in cutting to the exact figures, especially in fine work, than to show the relation of the figures on the square to degrees and minutes.

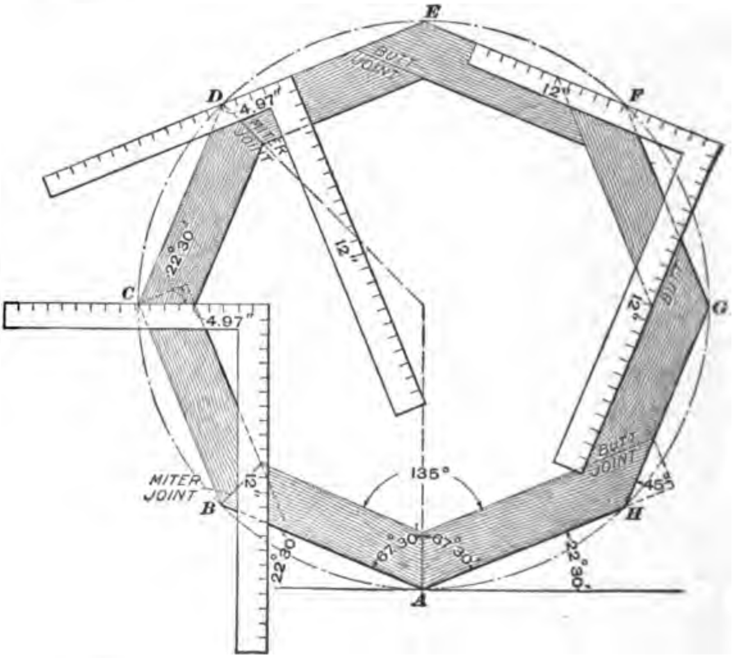


Fig. 30

The figures giving the cuts of squares, hexagons, and octagons will be found very useful in roof framing, and should therefore be kept in mind.

52. Marking a Miter-Box.—Fig. 31 illustrates a method of finding the marks on a miter-box so as to cut a strip of molding to fit around a column having the shape of a regular hexagon. By applying the square to the edge of the box, using the figures *12* and *6.93*, and marking along the 6.93-inch side, the correct miter will be found; then, by reversing the square and using the same figures, the corresponding miter cut will be obtained.

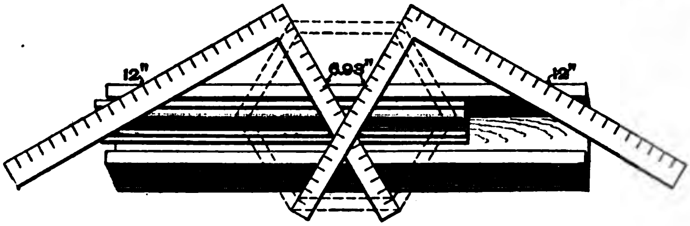


FIG. 31

ANGLES OF POLYGONS*

53. Table II gives the angles between sides, the miter and butt angles of polygons, and also the exact figures to use on the steel square to obtain the cut for miter and butt joints. The column marked Whole Numbers for Miter gives the nearest whole number to use on the square. These figures are not exactly correct, but are very close.

54. Inscribing a Polygon.—The last column of Table II gives the figures to use in order to find the radius of a circle that will fit around the outside of a regular polygon.

EXAMPLE.—The length of one side of an octagon is 20 inches. What is the radius of a circle that will go around, or circumscribe, the octagon?

SOLUTION.—The figures in the column Radius of Circumscribing Circle and opposite Octagon, under Name of Polygon, are 1.30656.

TABLE II

ANGLES OF POLYGONS

Number of Sides	Name of Polygon	Interior Angle Between Sides	Miter Angle	Butt Angle	Miter and Butt Joints Cut on Body			Whole Numbers for Miter		Radius of Circumscribing Circle = Side Multiplied by
					On Tongue	On Body For Miter	On Body For Butt	Tongue Inches	Body Inches	
3	Triangle	60°	60°	−30°	12	20.78	6.93	4	7	.57735
4	Square	90°	45°		12	12		Any whole number		.70711
5	Pentagon	108°	36°	18°	12	8.72	3.90	11	8	.85065
6	Hexagon	120°	30°	30°	12	6.93	6.93	7	4	1.00000
7	Heptagon	128° 34¼′ +	25°.43′	38.34	12	5.78	9.57	14½	7	1.15238
8	Octagon	135°	22.30	45°	12	4.97	12.00	17	7	1.30656
9	Nonagon	140°	20°	50°	12	4.37	14.30	22½	9	1.46190
10	Decagon	144°	18°	54°	12	3.90	16.52	9½	3	1.61803
11	Dadecagon	147° 16½′ +	16°.22′	57.16	12	3.52	18.67	14	3	1.77473
12	Dodecagon	150	15°	60°	12	3.22	20.78	13	3½	1.93185

Multiplying 20 inches by the quantity thus obtained, the length of radius is 26.13 inches. The diameter of the circle will therefore be 26.13 × 2 = 52.26 inches. Ans.

55. Inscribing a Circle in a Polygon.—To find the length of side of a polygon to fit around a circle of known radius, multiply the diameter of the circle by the figures under Miter and Butt Joints, in Table II, using the figures directly under For Miter.

Example.—Required, the length of one side of an octagon to fit around a column 18 inches, or 1.5 feet, in diameter.

Solution.—Under the column headed For Miter and opposite Octagon, under Name of Polygon, will be found the value 4.97. This value multiplied by 1.5 feet gives 7.45 inches, which is the length of one side of the octagon that will fit around the column.

ANGLE OF MITER

56. In the preceding articles, figures for obtaining the miter cuts of polygons have been given, but the reason for using these figures has not been stated. Before giving an explanation, however, it might be well to illustrate and explain more fully the **angle of miter.** In Fig. 32 are shown two boards that are mitered together at an angle of 125°. If the boards were joined at an angle of 180°, the cut across them would be square. Now, it is required to find out how many

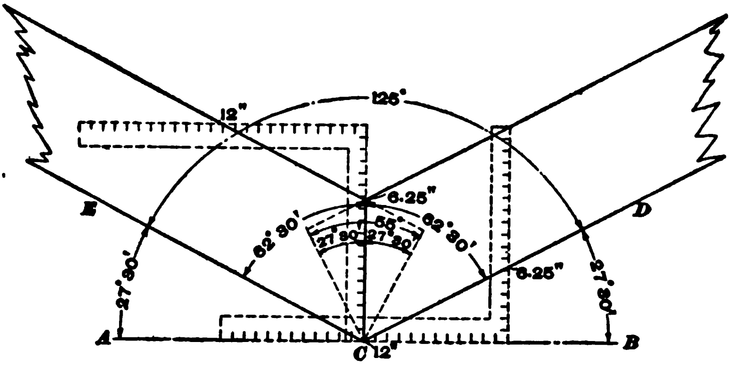


Fig. 32

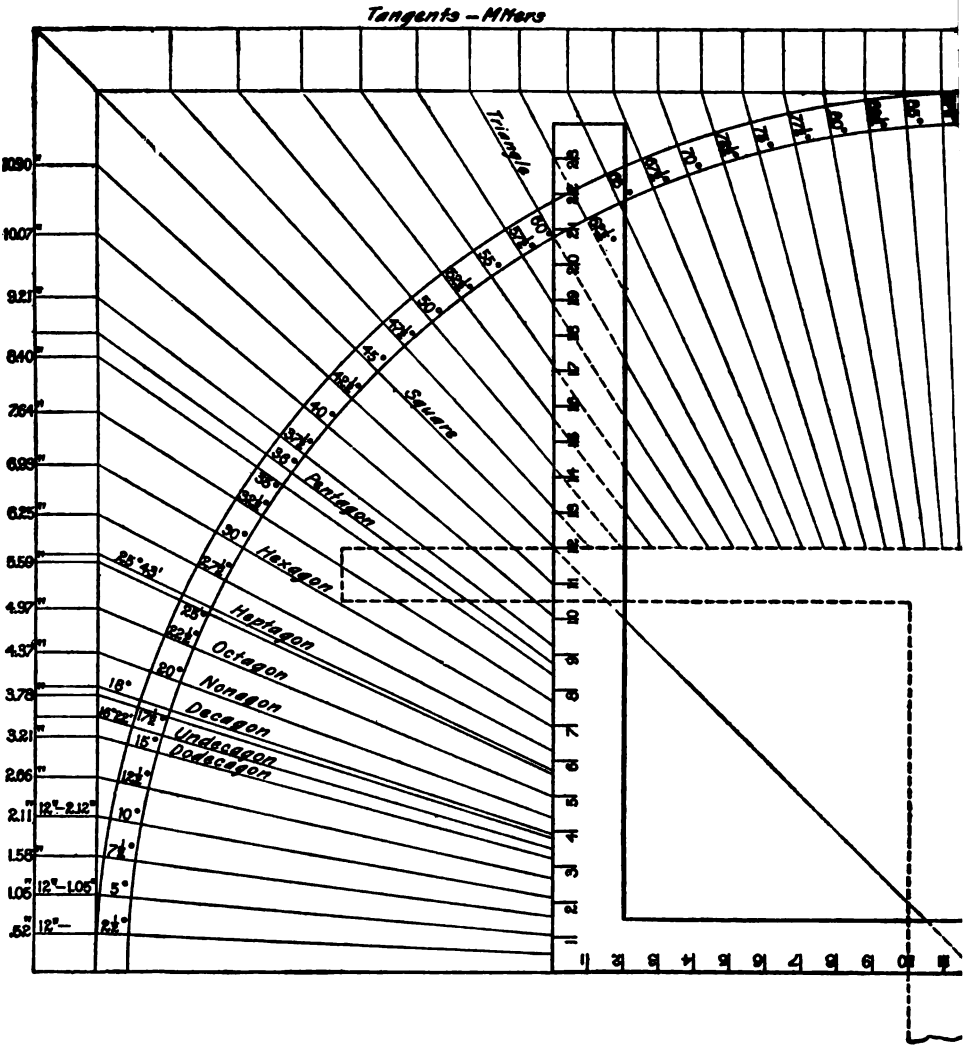
degrees must be cut off of each board, or, in other words, the miter angle. As the boards in the figure form an interior angle of 125°, it will readily be seen that they are 55° from a straight line, that is, 180° − 125° = 55°. Now, draw the line *AB* at right angles to the line of miter. The line of miter bisects the angle between the boards, and it is quite evident that one-half the difference between 180° and 125° will measure the angle *BCD*, making it equal to 27½°; consequently, *ACE* will be equal to 27½°. Each piece cut off of the boards, provided the boards are square, will therefore be 27½°.

If a plan of the boards were drawn, it would be an easy matter to lay the square on the plan and thus find the figures on the square; but very often it is impossible to have plans of all the work on hand. Furthermore, calculated figures are more accurate than scaled figures.

57. In Fig. 33 is shown the relation of the square to degrees, and how the figures are obtained for forming polygons or mitering pieces at different angles. In the previous article, it was shown that the miter angle for two pieces standing at an angle of 125° was 27½°. By inspecting the semicircle, Fig. 33, it will be seen that the line from *12* on the tongue of the square passing through 27½° on the semicircle passes through the body of the square at 6.25, or 6¼ inches. In other words, the tangent of 27½° is 6.25 inches, so that 12 inches on the tongue and 6.25 inches on the body, cutting along the body of the square, will miter two pieces when the interior angle is 125°, which will readily be seen by referring to Fig. 32.

58. The polygon miters from three to twelve sides are also shown in Fig. 33; likewise, the figures to use on the square are marked on the margin. It will be observed that these figures are derived from the body of the square and are determined by a line drawn from *12* on the tongue to the degree mark corresponding to the miter angle.

A line drawn from 12 on the tongue of a square to the 22½° mark on the circle passes through the body at 4.97 inches.


Tangents – Miters
10.90"
10.07"
9.21"
8.40"
7.64"
6.93"
6.25"
5.59"
4.97"
4.37"
3.78"
3.21"
2.66"
2.11"
1.58"
1.05"
.52"
12"-2.12"
12"-1.05"
12"–
2½°
5°
7½°
10°
12½°
15°
16°22'
17½°
18°
20°
22½°
25°
25°43'
27½°
30°
32½°
35°
36°
37½°
40°
42½°
45°
47½°
50°
52½°
55°
57½°
60°
62½°
65°
67½°
70°
72½°
75°
77½°
80°
82½°
85°
Triangle
Square
Pantagon
Hexagon
Heptagon
Octagon
Nonagon
Decagon
Undecagon
Dodecagon
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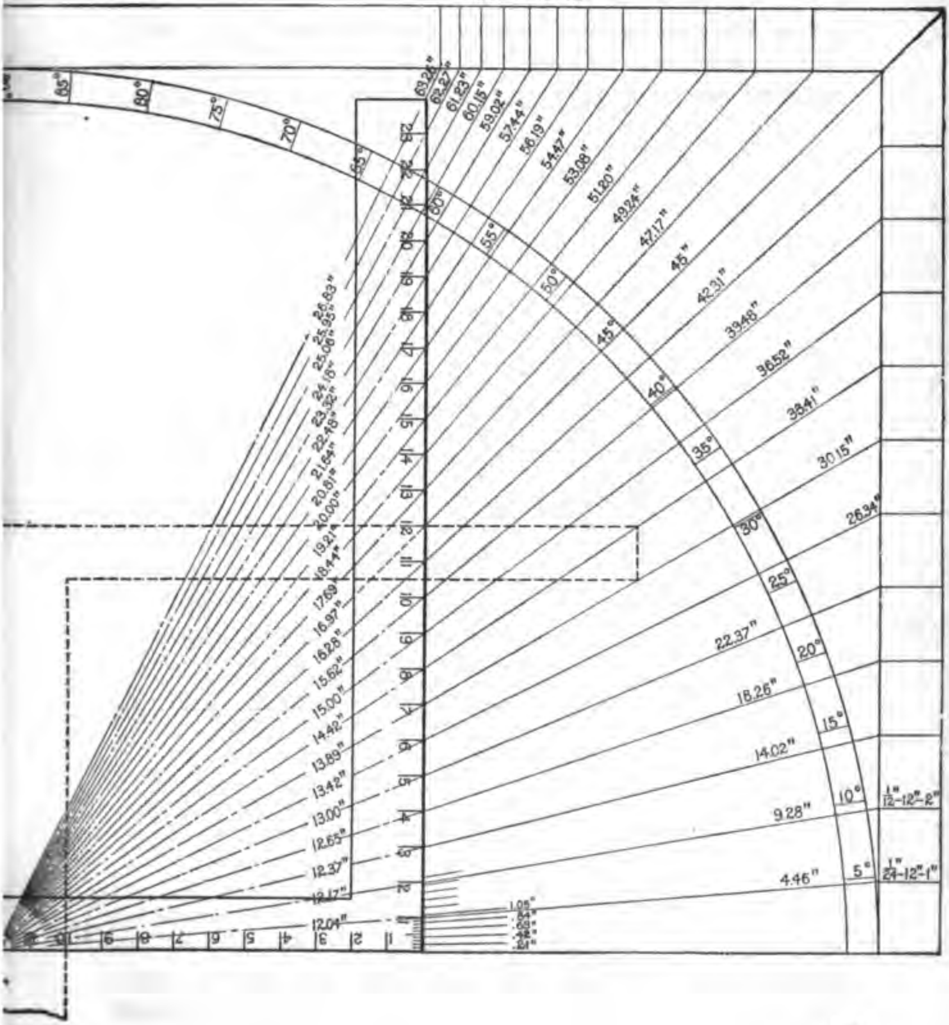
Roof Pitches



As 22½° is the miter angle for an octagon, then the correct figures to use in laying out an octagon are 12 and 4.97 inches. In other words, 4.97 inches is the tangent of 22½°.

59. Fig. 34 shows the construction of an octagon, using the angles as shown in Fig. 33. To find the center of the octagon, draw a perpendicular line from 6 on the body of the square, intersecting the 22½° line at *C*. This point will also be the center of either an inscribed or a circumscribed circle. It will readily be seen that the line *A C* is half the length of one of the sides. The bridge measure of 12 and 4.97 is the diameter of the circumscribing circle. The diameter of the inscribed circle may be found by dividing the length of the side by the miter. The bridge measure of

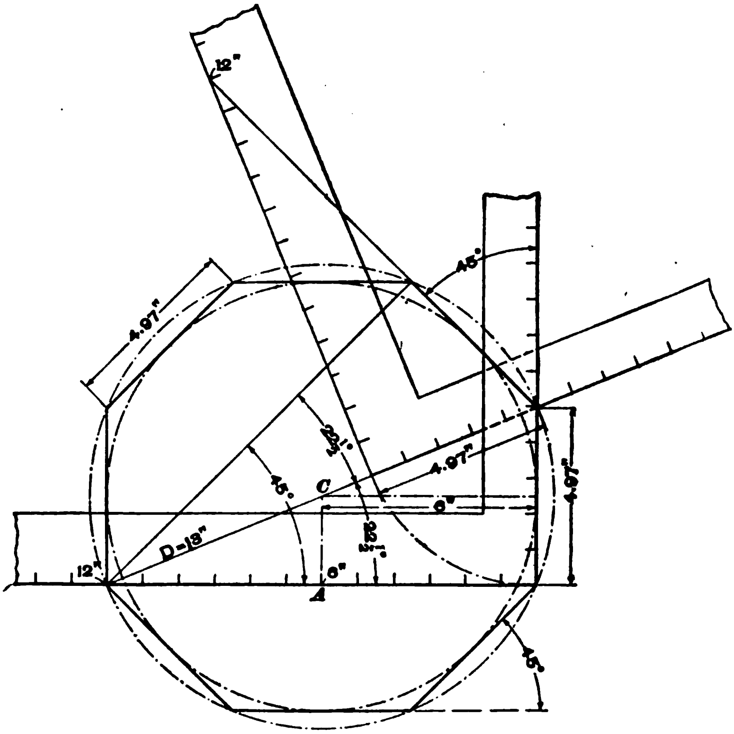


FIG. 34

12 and 4.97 is 12.988, or, approximately, 13. This figure 13 plays a very important part in octagon construction.

As will be noted, the radius of the inscribed circle is 6 inches; therefore, the diameter is 12 inches, or 1 foot. From the foregoing explanation, the diameter, in feet, of the inscribed circle can be found by dividing 4.97 by 4.97, which is equal to 1.

60. Fig. 35 shows the foregoing principles as applied in the construction of a hexagon. The only difference is in the angles used; consequently, the bridge measure is different. The radius of the inscribed circle is the same, and is

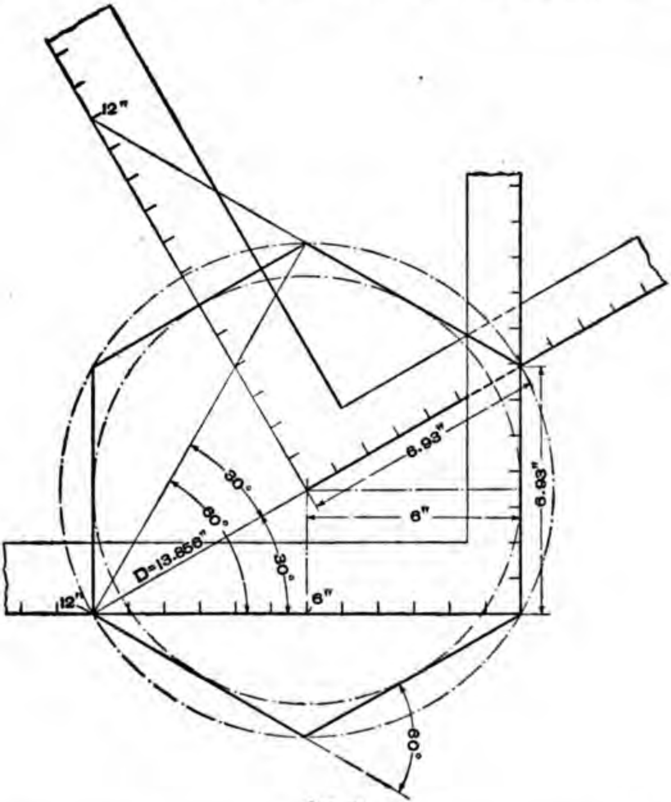


Fig. 35

found in the same way as was explained for finding the radius of a circle inscribed in an octagon. The bridge measure of 12 and 6.93 is 13.856 inches. The foregoing remarks will apply to all regular polygons.

DESCRIBING CURVED OUTLINES

61. To Describe a Circle With the Square.—In order to describe a circle with a square, first drive two pins or nails *c* and *d* on a line *A B*, as shown in Fig. 36, and the distance between the points *c* and *d* will be the desired diameter of the circle. Then, with the inner edges of the square pressing against the pins and a pencil point placed as at *e*, revolve the square around the pins, and thus obtain one half of the circumference. Reverse the square for the other half.

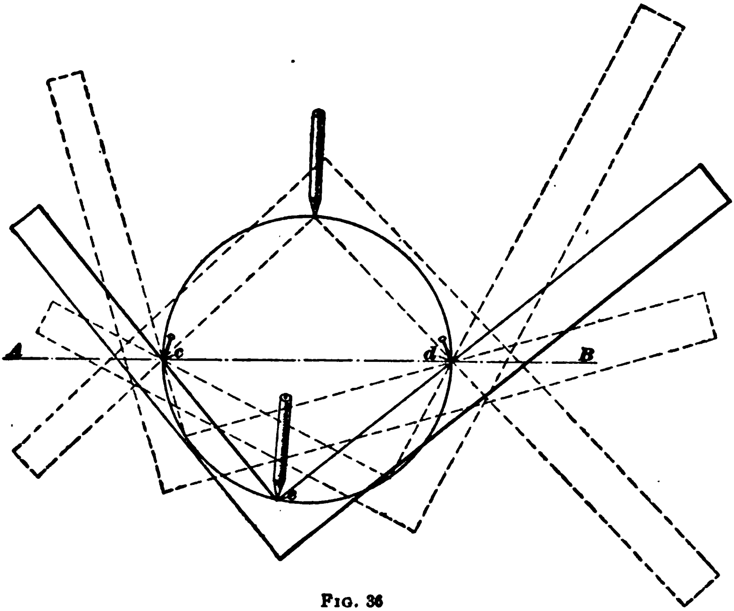


FIG. 36

This same principle may be applied in testing a block of wood that has been gouged out so as to receive a

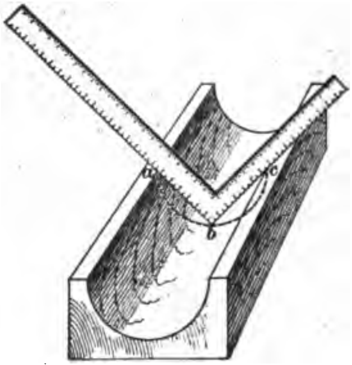


FIG. 37

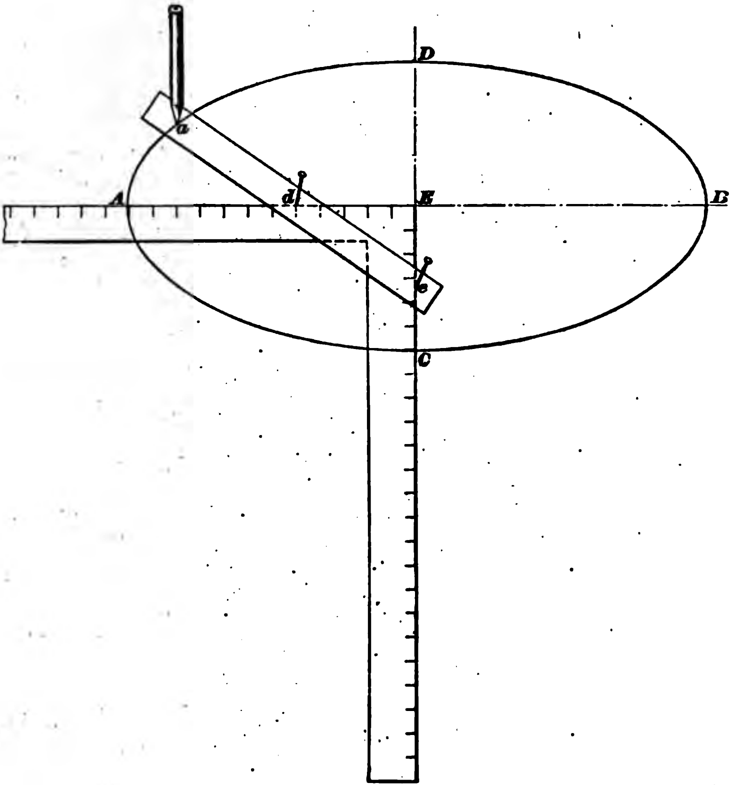


FIG. 38

cylindrical body, such as a core box for a cyclindrical core. To test the work to see that it is true, place a square as shown in Fig. 37. If any part has not been cut out deep enough, the corner *b* will touch that part, and the edges *a* or *c* will not come in contact with the edge of the box. If any part has been cut too deep, the point *c* will not touch that part when the edges of the square rest on the sides of the box. The reason for this is that the angle between two lines drawn from any point on the circumference of a circle to the extremities of the diameter is a right angle.

62. To Describe an Ellipse With the Square.—To describe an ellipse with a square, first draw two lines at right angles to each other, as AB and CD, Fig. 38. Let AB represent the longitudinal axis, and CD the transverse axis, both being of the desired length. Place the square so that the heel will rest at the intersection of the axes, as at E, and the body and tongue will rest on the transverse and longitudinal axis, respectively. Take a thin strip of wood, and on it lay off $ad = ED =$ half the transverse axis, and $ea = EA =$ half the longitudinal axis. Drive nails into the strip as at *e* and *d*, and make a hole, as at *a*, large enough to admit a pencil point. Now, place the strip as shown, and move the point *a* from A to D with *e* and *d* always touching the square; then, the point *a* will describe one-fourth of the ellipse. In the same way, by reversing the square, the rest of the ellipse may be drawn.

This method may be used in constructing centers for elliptical arches, and ellipses from a very small size up to 36 in. × 48 in. may thus be made. The method described is on the same principle as the elliptical trammel, the steel square taking the place of the trammel frame.

LAYING OUT VARIOUS PARTS OF A STRUCTURE

63. Laying Out Stairs.—To obtain the figures on a square required to lay out a stringer for a straight stairway, it is first necessary to know the rise and the run, or the distance between floors and the length of space available. In Fig. 39 the distance between floors is 10 feet 6 inches, or 126 inches, and the run is 12 feet 9 inches, or 153 inches. There will be 18 risers. To find the height of each riser, divide 126 inches by 18, which equals 7 inches. The width of the threads are found by dividing the run, 153 inches, by 17, which equals 9 inches. Then, by taking 7 inches on the body and 9 inches on the tongue, and marking along the body for the tread and along the tongue for the riser, the stringer may be marked out as shown in the illustration. As the floor at the landing makes one of the steps, there is one tread less than there are risers.

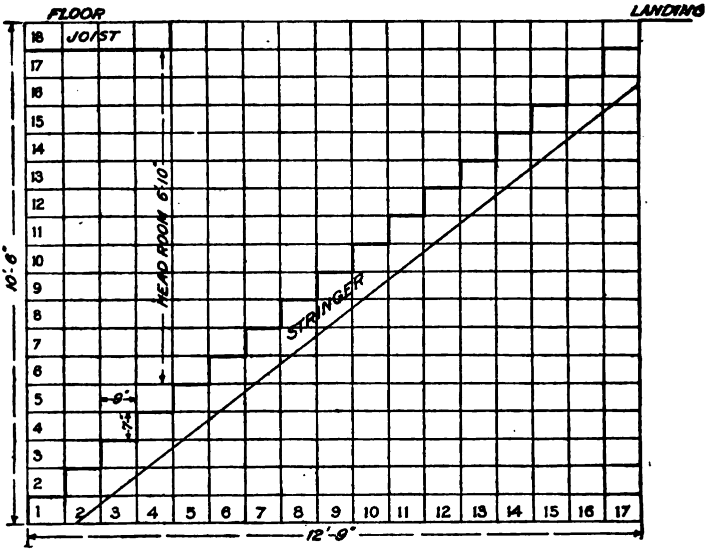


FIG. 39

64. Laying Out Stair Stringers.—In an open-stair stringer, the risers and stringers are mitered, and although they stand at an angle of 45° to each other, the miter, owing to the pitch of the stair stringer, is not a square one, but changes with the pitch. In Fig. 40 (*a*) is shown how the cut on the stringer may be obtained by means of the square. The pitch board at (*b*) shows a tread of 8 inches and a rise of 6 inches; the hypotenuse is therefore 10 inches. Take the length of the tread, which in this case is 8 inches, on the tongue of the square, and the length of the hypotenuse, which is 10 inches, on the body of the square, and apply to the stringer as shown at (*a*), marking along the body for the miter cut. The cut on the riser will be a 45° angle.

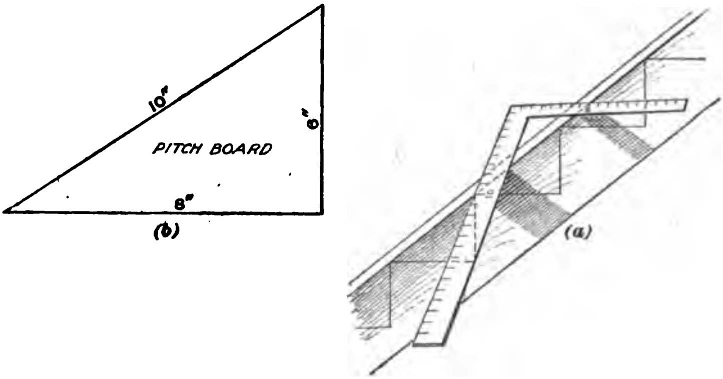


FIG. 40

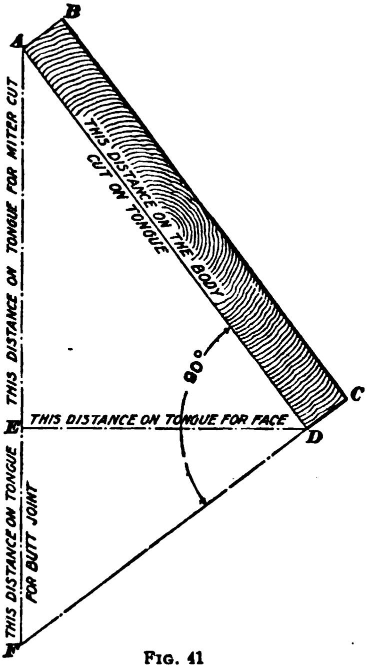

B
A
THIS DISTANCE ON TONGUE FOR MITER CUT
THIS DISTANCE ON THE BODY
CUT ON TONGUE
90°
C
E
THIS DISTANCE ON TONGUE FOR FACE
D
THIS DISTANCE ON TONGUE FOR BUTT JOINT
F

FIG. 41

65. Laying Out Square Hoppers.—A thorough knowledge of how to obtain the several cuts in hoppers will be of great assistance in roof framing. In Fig. 41 is shown a method of laying out hopper bevels with the steel square. While there are a great many methods for finding the cuts for hopper bevels, the one shown is the simplest and perhaps the easiest to remember.

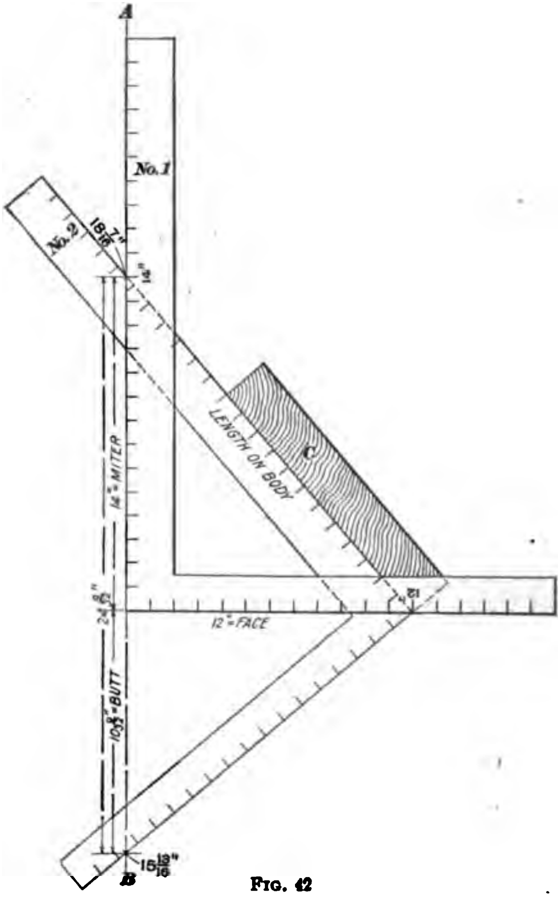


FIG. 42

In the illustration, AF and ED are two lines at right angles to each other; $ABCD$ represents the cross-section of one side of the hopper, and consequently the pitch. From D draw DF at right angles to AD, intersecting the vertical line AF. Then, the distance AD taken on the body of the square and *A E* taken on the tongue of the square, by cutting along the tongue, will give the cut across the square edge for the miter; *A D* on the body and *E D* on the tongue, cutting along the tongue, will give the cut across the face of the board; *A D* on the body and *E F* on the tongue, cutting along the tongue, will give the cut for the butt joint.

66. It is not necessary to make a drawing in order to get the numbers used on a square to lay out these several cuts. Fig. 42 illustrates the method of using the square. *A B* represents a line, or a straight edge. It is desired to find the several cuts on the plank *C* in order to make a square hopper, the hopper to pitch 14 inches in 12 inches, or, in other words, the rise is 14 inches and the run is 12 inches. Place square *No. 1*, as shown, along the line, or straight edge, and make a mark at 14 inches on the body; also, scribe along the tongue and make a mark at 12 inches. Next, place the square as shown at *No. 2*, with the heel resting on the mark made at 12 and the body on the mark made at 14. It will be found that the mark on the body of square *No. 2*, where it rests at 14, will be $18\frac{7}{16}$ inches, and that the tongue of square *No. 2* will rest on line *A B* at $15\frac{13}{16}$ inches. Now, take the bridge measure of $18\frac{7}{16}$ and $15\frac{13}{16}$ inches and it will be found to measure $24\frac{9}{32}$ inches. The rise of the hopper is 14 inches in 12 inches; therefore, subtract 14 from $24\frac{9}{32}$

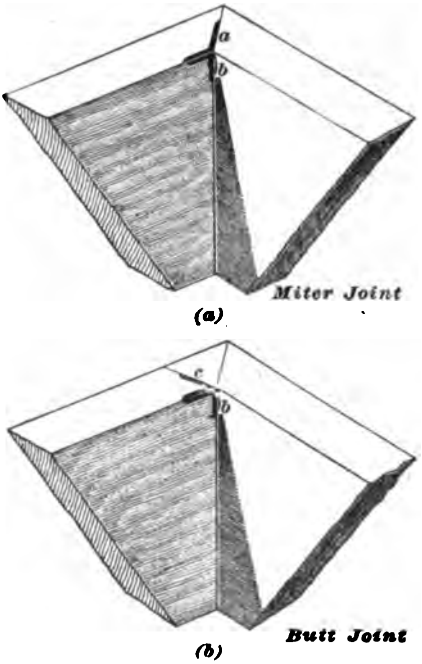


FIG. 43

and $10\frac{9}{32}$ inches will remain. To use these figures, take $18\frac{7}{16}$ inches on the body of the square and 14 inches on the tongue of the square for the miter, $18\frac{7}{16}$ inches on the body and 12 inches on the tongue for the face, and $18\frac{7}{16}$ inches on the body and $10\frac{9}{32}$ inches on the tongue for the butt joint.

67. Fig. 43 shows the several cuts in a hopper. Illustration (*a*) shows the miter joint at *a* and the face cut at *b*, while in (*b*), *c* shows the butt joint, and *b*, the face cut. The angle for the face cut is the same whether a miter joint or a butt joint is used.

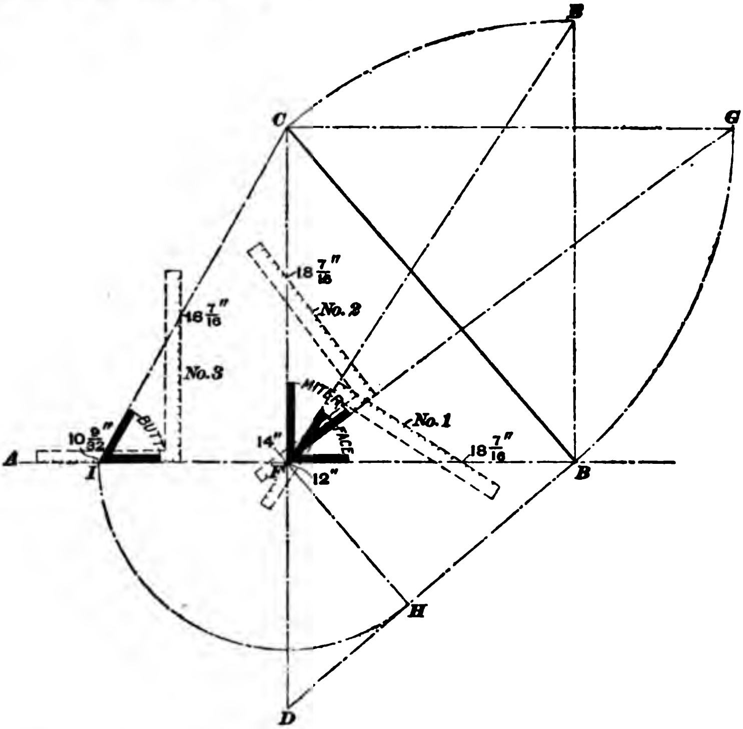


FIG. 44

68. In Fig. 44 is presented another method of finding the several cuts for a hopper. Make *A B* and *C D* at right angles to each other; then, draw the line *C B* at the desired pitch. In this case, the pitch is the same as that shown in Fig. 42. With *B* as a center and *BC* as a radius, draw the arc *CE*, intersecting the line *BE* drawn at right angles to *AB*. Connect *E* with *F*; then, the angle *EFB* is the correct angle to cut across the face of the board. Square *No. 1* shows the application.

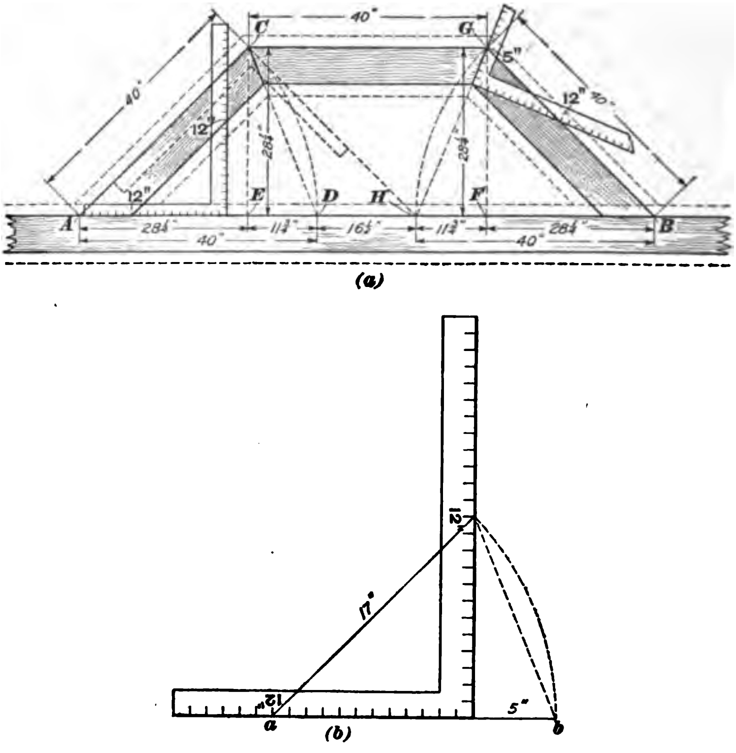
To find the miter cut on the square edge of the board, take the points *C* and *B* in the compasses and describe the arc *BG* with *C* as a center. Connect *G* with *F*; then, the angle *GFC* is the correct angle for miter. Square *No. 2* shows the application.

In order to get the butt joint on the square edge, draw the line *BD* at right angles to *CB*; then, at some point on the line *BD*, erect a perpendicular passing through *F*. With *F* as a center, and a radius *FH*, draw the arc *HI*, intersecting the line *AB* at *I*. Connect *I* and *C*; then, the angle *CIF* will be the correct cut for the butt joint. Square *No. 3* shows the application.

69. The principles underlying the solution of hopper cuts are of inestimable value, especially for roof framing and for all splayed work. A hipped corner of a roof is nothing more than an inverted hopper. The bevels found for the face and miter cuts for a hopper are identical with the bevels necessary to cut the face and miter of roof boards that intersect on a hip or in a valley. These bevels are also the same as the bevels required to cut purlins that intersect either against the sides of hips or valleys, or on the back face of same. The same figures on the square would be used for mitering a splayed molding, as for a hopper with equal pitch.

The relation of hoppers to roofs will be taken up in the articles dealing with roof construction.

70. Laying Out an Octagon Bay Window.—A method of laying out an octagon bay window is shown in Fig. 45 (*a*), where *AB* represents the line of the building. The sides of the octagon are 40 inches long. To determine the length that will be taken up along the sill, it will be necessary to know the length from *A* to *E*, or the base of the right triangle with a 40-inch hypotenuse. By referring to Fig. 45 (*b*), it will be seen that the bridge measure, or the hypotenuse, of 12 inches on the tongue and 12 inches on the body is practically 17 inches. Now, by revolving the 12-inch mark on the body to the line of the tongue, produced, it will be seen that the line from *a* to *b* is 5 inches longer than the 12 inches on the tongue. Then, to find the base, knowing the hypotenuse, multiply the hypotenuse by $\frac{12}{17}$. In Fig. 45 (*a*), the hypotenuse is 40 inches, and $40 \times \frac{12}{17} = 28.23$, or 28¼, inches. The distance, then, from *A* to *E* is 28¼ inches, and the distance from *F* to *B* is also 28¼ inches. It is quite evident that the distance from *E* to *F* is equal to



(a)

(b)

FIG. 45

CG, and is therefore 40 inches. Thus, the total distance along the sill from *A* to *B* is $28\frac{1}{4} + 28\frac{1}{4} + 40 = 96\frac{1}{2}$ inches.

The distance may also be found in the following manner: It is quite evident that the distance *AD* is equal to 40 inches, and that the distance *BH* is equal to 40 inches. Now, if the distance *DH* were known, the length of the sill could be found. The distance *AE* has already been shown to be $\frac{12}{17}$ of 40, and the distance *AD*, $\frac{17}{17}$ of 40. Therefore, *D* is over on *EF* $\frac{5}{17}$ of 40, and the distance *FH* is over on *EF* $\frac{5}{17}$ of 40. Thus, *DH* is $\frac{7}{17}$ of 40, making *DH* equal to very nearly $16\frac{1}{2}$ inches.

71. The squares in Fig. 45 (*a*) show the method of getting the cuts in order to fit the sills in place. The dotted line from *C* to *D* shows the miter, and by taking $28\frac{1}{4}$ inches on the body of the square and $11\frac{3}{4}$ inches on the tongue of the square, cutting along the tongue will give the miter cut. These are not the figures used on the square in Fig. 45, but they bear the same relation, as will be seen by the proportion $28\frac{1}{4} : 11\frac{3}{4} = 12 : 5$. By referring to Fig. 45 (*b*), the figures *12* and *5* may be verified. If the distance on the house is given, the length of one side of the octagon may be found by dividing the distance by $2\frac{5}{12}$. To find the distance on the house when the side is given, multiply the length of one side by $2\frac{5}{12}$.

72. Miter and Face Cuts for Any Angle and Any Splay.—In Fig. 46 is shown a method of finding the figures on the square that will give the miter and face cuts for two pieces meeting at an angle of 135°, and with a splay, or inclination, of 10 inches in 12 inches from the vertical. In other words, the figure represents one corner of an octagonal hopper. The line *AB* is the line of miter, in plan, and *CD* is the inclination of the side.

From the base line *EA*, erect a perpendicular, drawn to some convenient scale at *C*, making the line 12 inches long. Then, from the point *H*, draw the line *HI* parallel with the base, making this line 10 inches long. Connect *C* with *I*, and with *C* as a center, describe the arc *HD*; then *CD* will

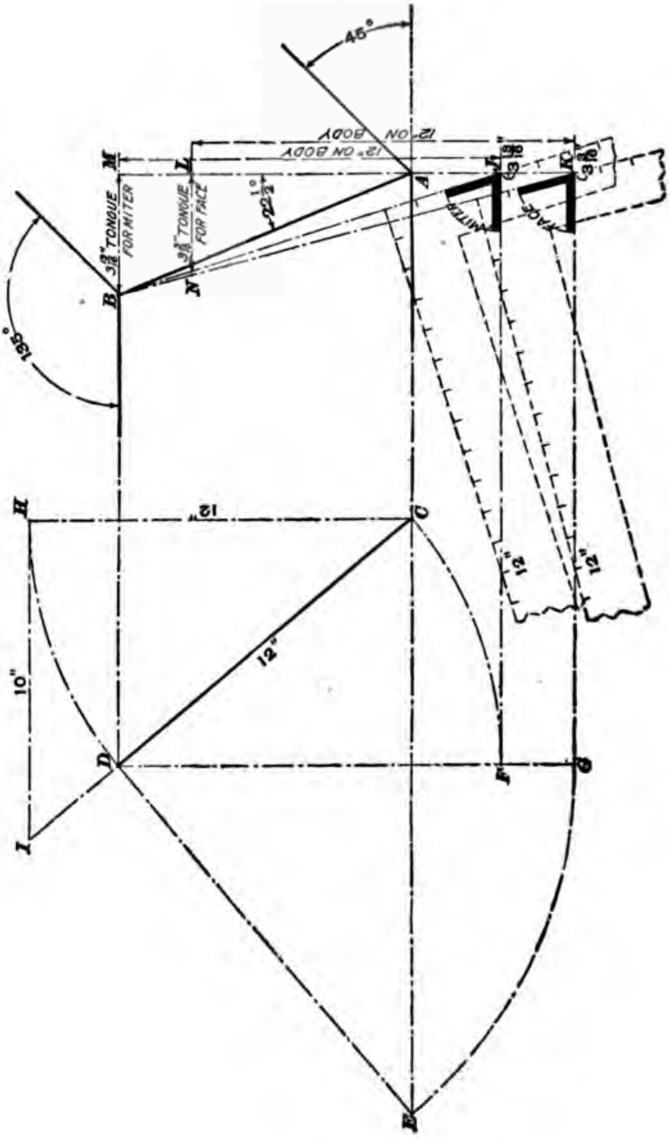

45°
135°
M
L
A
B
N
J
K
12" ON BODY
12" ON BODY
3 3/16" TONGUE FOR MITER
3 3/8" TONGUE FOR FACE
22 1/2°
3 3/16
3 3/8
MITER
FACE
12"
12"
H
C
12"
12"
10"
I
D
F
G
E

FIG. 46

be the inclination and the correct width of the board. From the point *D*, let fall a perpendicular to the line *EA*, producing the line indefinitely below *EA*. At *D*, erect a perpendicular to *CD*, meeting the base line at *E*. With *D* as a center, describe the arc *EG*; also, with the same center, describe the arc *CF*. At any convenient point on the base line *EA*, as at *A*, construct the angle that the two pieces make. In this case, the angle that one side makes with the other side is 180° − 135° = 45°. From *A*, bisect the angle of 135°, also erect a perpendicular extending indefinitely on both sides of the line. From *D*, draw a line parallel with the base line and intersecting the bisecting line at *B*; then, *AB* will be the miter line in the plan. From *G* and from *F*, draw lines parallel with the base line and intersecting the vertical line from *A* at the points *K* and *J*, respectively. Connect *K* and *J* with *B*; then, the angle formed at *K* will be the face angle, and that at *J*, the miter angle. From *K*, measure along the vertical line 12 inches to *L*. At *L*, erect a perpendicular to the vertical line and measure the distance *NL*. Then, for the face cut, take 12 inches on the body of the square and $3\frac{3}{16}$ inches on the tongue of the square, and the tongue will give the cut. For the miter cut, measure 12 inches from *J* along the vertical line to *M*; also

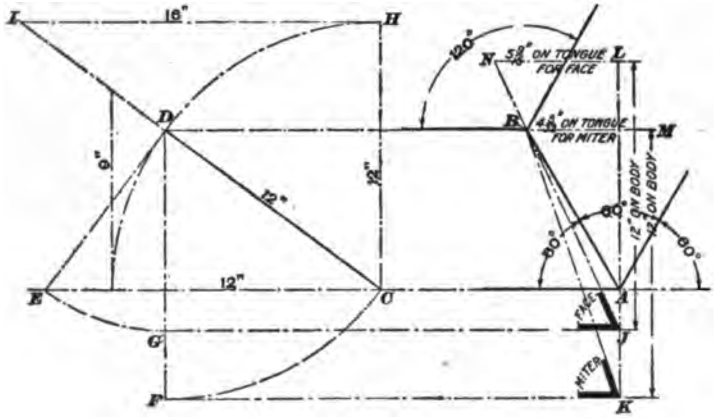


Fig. 47

measure the distance from *M* to *B*, which is $3\frac{13}{16}$ inches. Then, take 12 inches on the body of the square and $3\frac{13}{16}$ inches on the tongue of the square, and cut along the tongue. The squares in the illustration show the application.

73. In Fig. 47 is shown the same method as applied to a hexagonal figure. The splay of the side is 16 inches in 12 inches from the vertical, or 9 inches in 12 inches from the horizontal. It will be observed that because the angle from the vertical is more than 45°, the angles for the miter and for the face cuts are the reverse of those shown in Fig. 46. These figures will apply to a square hopper or to any angle.

THE STEEL SQUARE
(PART 2)

ROOF FRAMING

ROOF MEMBERS

1. The steel square may be used to solve many problems that would be very intricate without its aid; but its greatest usefulness is in roof framing, to which class of work it seems particularly adapted. In treating on the uses of a steel square for roof framing, the several members of a roof will be considered separately, and then examples of complete roofs of both equal and unequal pitch will be given.

As the methods of using the steel square differ in various sections of the country, a diversity of methods will be given, so that a broad knowledge may be obtained of the instrument and of the different ways of using it to obtain the same results.

2. Run, Rise, and Pitch.—The **run** of a rafter is the horizontal distance from the extreme end of the foot, or the outer edge of the plate, to a plumb-line from the ridge.

The **rise** of a rafter is the perpendicular distance from the top of the ridge end of the rafter to the level of the foot, or of the plates.

The **pitch** of a roof is the proportion that the rise bears to the whole width of the building.

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3. Fig. 1 illustrates the terms run, rise, and pitch, and shows the *length* of the rafter. It should be remembered, however, that the term length of rafter does not include the projection over the plate. As will be observed, the span of the section of roof shown in the figure is 24 feet and the rise is 8 feet; consequently, the pitch is $\frac{1}{3}$, because 8 is contained in 24, 3 times, or 8 is $\frac{1}{3}$ of 24. If the rise were 12 feet, the roof would be $\frac{1}{2}$ pitch, because 12 is $\frac{1}{2}$ of 24.

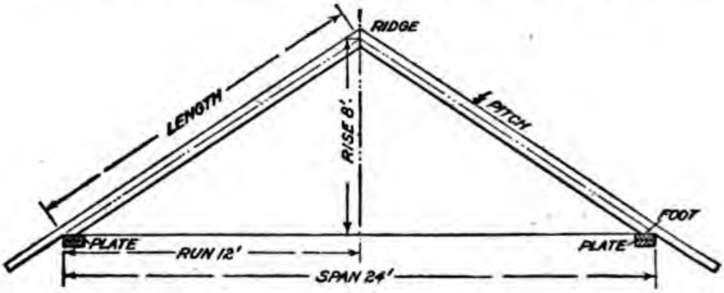


FIG. 1

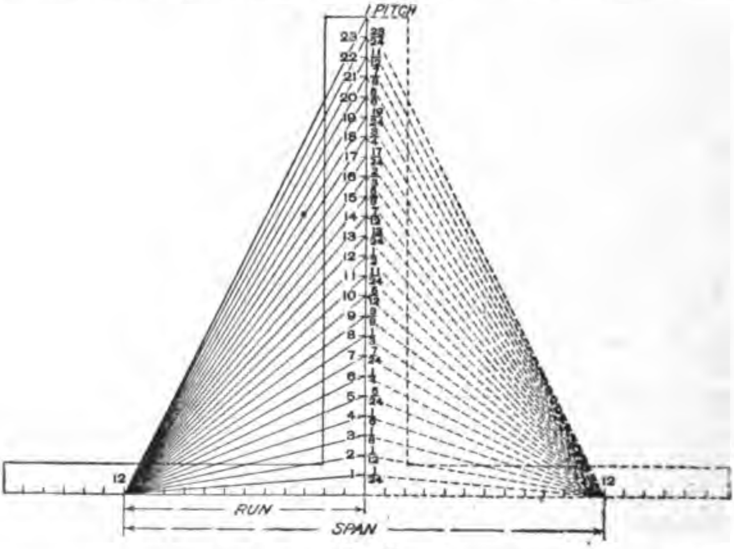


FIG. 2

4. In Fig. 2 are shown the pitches of roofs having a rise of from 1 inch to 24 inches per foot. By considering the span of a building as 24 inches, the pitch of the roof will be designated as some proportional part of the span. For instance, if the rise is 16 inches in a run of 12 inches, then the pitch will be $\frac{16}{24}$, or $\frac{2}{3}$, as has already been explained. Fig. 2 is introduced at this place in order to more fully illustrate the term *pitch*, as it is very important that the rise per foot should be known even if a certain pitch or total rise is given.

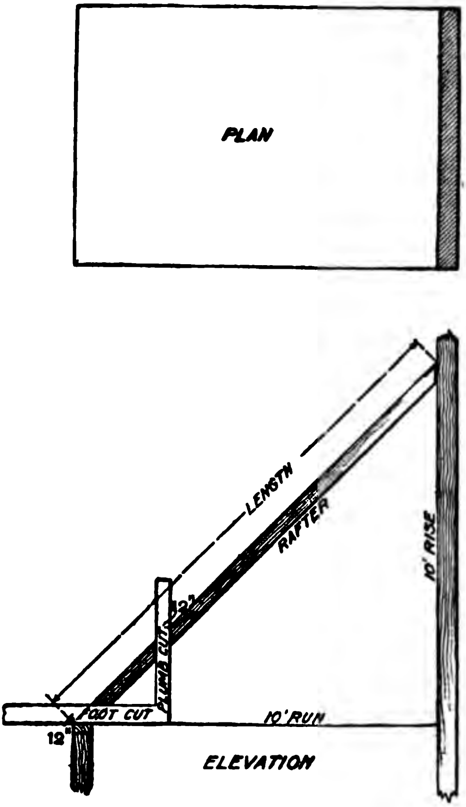


FIG. 3

TYPES OF RAFTERS

COMMON RAFTERS

5. Laying Out Common Rafters. In Fig. 3 is shown a plan and elevation of a *shed*, or *lean-to*, *roof*, which is one-half of a saddle roof. This figure also illustrates a method of laying out a common rafter, both the run and the rise of the rafter being 10 feet. As placed in the illustration, the square shows a rise of 12 inches to a foot of run, which is the same as a $\frac{1}{2}$ pitch. The figures to be used on the square, therefore, are 12 inches on the body and 12 inches on the tongue for both the foot- and the plumb-cuts. The length of the rafter can be found by stepping along the rafter timber ten times, because the run is 10 feet.

6. When a portion of a common rafter projects beyond the plate, it can be laid out as shown in Fig. 4, which illustrates a section of a saddle roof having a run of 13 feet and a rise of 6 feet 6 inches. The squares placed at the foot and at the top of the rafter in (*a*) show the figures *12* on the body and *6* on the tongue as the ones to be used to obtain the foot- and the plumb-cuts. As the run is 13 feet, it will be necessary to step along the rafter thirteen times to obtain the length of the rafter. This roof is a ¼-pitch roof, the rise being one-quarter of the span of the building. One foot, or 12 inches, is the standard measurement taken on the body of the square to represent the run. For the rise, the figure is determined by the number of inches the roof rises per foot of run. As shown in the figure, the lower end of the rafter projects the distance *A B* beyond the face line of the wall plate. This distance should therefore be added to the length of the rafter found by stepping thirteen times.

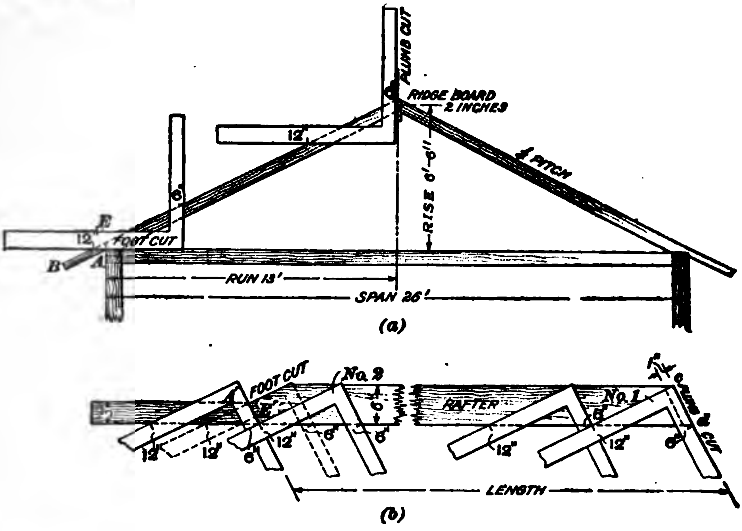


FIG. 4

To lay out the rafter, including the projecting portion, proceed as shown in Fig. 4 (*b*). Place square *No. 1* at one end of the rafter timber, with the 12-inch mark on the body and the 6-inch mark on the tongue, even with the top edge of the timber, and then mark along the tongue, as shown at *c d*, for the plumb-cut. Step along the timber thirteen times to *A'*, or to the 12-inch mark on square *No. 2*. Place the square once more, with the same figures, and from *A'* draw the line *A' E'*. Mark a point on this line at the required width of the projecting part of the rafter, as at *E'*, say 3 inches wide; then, place the square at the mark *E'*, as shown by the dotted square, and draw a line for the foot-cut. It will be observed that this mark is at right angles to the tongue of the other squares and that the rafter has been raised the distance *A E* above the plates, as shown in Fig. 4 (*a*).

The rafter is not ready to put in place, however, until a portion of the top equal to one-half the thickness of the ridge board is cut off. If the ridge board is 2 inches thick, measure back 1 inch at right angles to the plumb-cut at the top of the rafter. This cut is shown in (*b*). In practice, instead of making two cuts of the top of the rafter, allowance is made for the ridge board and the necessary thickness removed in one cut.

7. To lay out a common rafter when the run contains a fraction of a foot, resort is had to the method illustrated in Fig. 5, which shows at (*a*) a gable end of a building that is 21 feet 2 inches wide from plate to plate. For a building of this width, the rise and the run of the rafter are each 10 feet 7 inches; consequently, the roof is ½ pitch, because one-half of the span equals the rise. The figures to use on the square for the cuts are 12 inches on the body and 12 inches on the tongue.

To lay out the rafter proceed the same as was done in Fig. 4 (*b*). The distance *a b*, Fig. 5 (*b*), represents the length of the rafter for a 10-foot run. Place the square again from *a*, with 12 inches on the body and 12 inches on the tongue. From the heel of the square, measure 7 inches along the body to *c*. Slide the square backwards to *d*, and draw the line *de*. It will be noticed that the point *d* is determined by the intersection of a plumb-line drawn from *c*, with a gauge line indicating the thickness of that portion of the rafter which projects beyond the plate. By this operation, it is clearly shown that an addition to the length of the rafter is obtained, and that it is equal to the distance *df*. If the run of the building were 10 feet, the foot-cut of the rafter would be at *fg* instead of *de*.

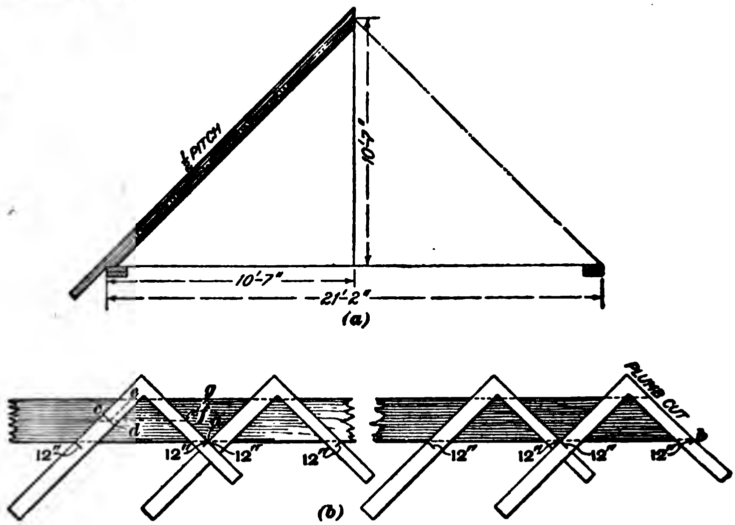


Fig. 5

HIP RAFTERS

8. Laying Out Hip Rafters.—Owing to the fact that a hip is placed diagonally to the plates of a building, and that the pitch is less than the common rafter, the cuts are somewhat different. Fig. 6 (*a*) shows the plan of a true hip roof with a span of 28 feet and a rise of 8 inches per foot of run. The figures to be used on the square to obtain the cuts of the common rafter are 12 inches on the body for the foot-cut and 8 inches on the tongue for the plumb-cut.

The correct length of the common rafter may be found by multiplying the bridge measure, which is $14\frac{7}{16}$ inches, by the run, which is 14 feet. Thus, $14\frac{7}{16} \times 14 = 202$ inches, or 16 feet 10 inches.

To find the cuts for the hips, take 17 inches on the body of the square for the foot-cut and 8 inches on the tongue of the square for the plumb-cut. The length of the hip rafter can be found by taking the bridge measure of 17 inches and 8 inches, which is $18\frac{13}{16}$ inches, and multiplying it by the run of the common rafter, which is 14 feet. Thus, $18\frac{13}{16} \times 14$ = approximately 264 inches, or 22 feet.

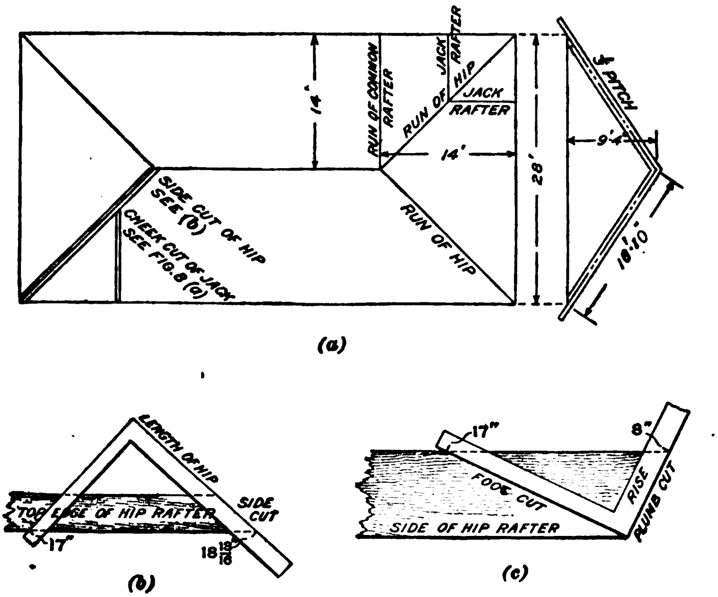


FIG. 6

In any true hip or valley, the figures to use on the square to obtain the foot- and the plumb-cuts, are 17 inches on the body and the rise per foot of the run of the common rafter on the tongue.

9. In order to make the hip or valley rafter fit close to the ridge, another cut besides the plumb-cut is required at the top. This cut is called the **side cut** of the hip or valley. In order to obtain the side cut, take 17 inches on the tongue of the square, and the length of the hip on the body of the square, and cut along the body.

In Fig. 6 (*b*), the length of the hip per foot of run is $18\frac{13}{16}$ inches; consequently, by taking 17 inches on the tongue of the square and $18\frac{13}{16}$ on the body of the square and cutting along the body will give the side cut for the hip rafter for a $\frac{1}{3}$-pitch roof. As shown in (*b*), the square is applied to the

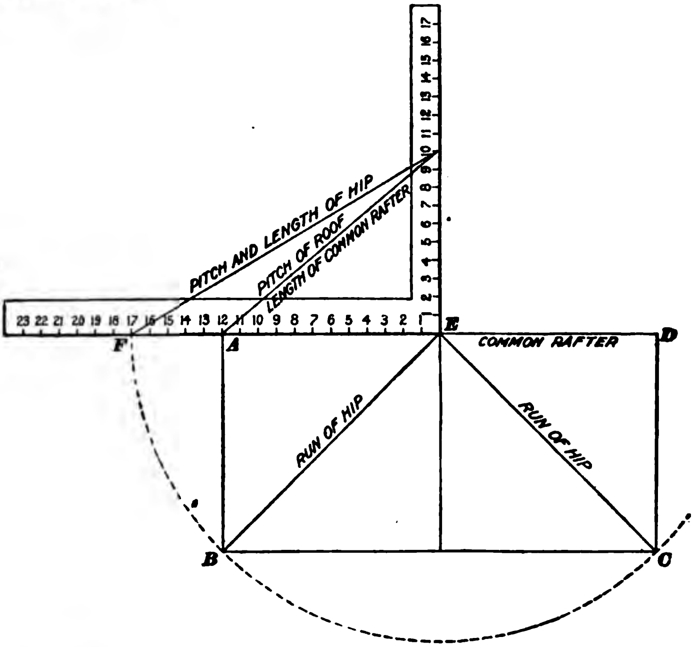


FIG. 7

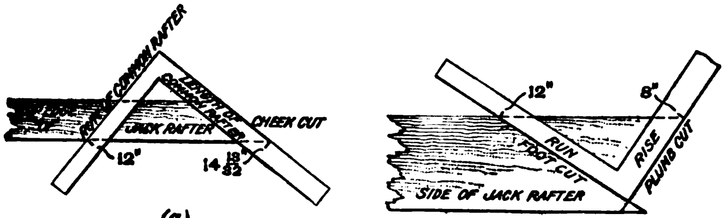
top edge of the hip rafter at the figures 17 and $18\frac{13}{16}$ on the square, which are the figures to use for the $\frac{1}{3}$-pitch roof.

10. In (*c*) is shown the application of the square to find the foot- and the plumb-cuts for the hip in a $\frac{1}{3}$-pitch roof. The same figures will also give the cuts for a valley rafter in a $\frac{1}{3}$-pitch roof. The method described here is known as the **17 method.**

The reason for using 17 inches on the body of a steel square when laying out a hip rafter will be made clear by an inspection of Fig. 7. Here, $ABCD$ represents one end of a hip roof 24 inches wide, in which ED is the run of the common rafter, and BE and CE the run of the hip rafter. If the run of hip BE is revolved to the line of the common rafter, the distance EF will be 17, or, to be exact, 16.97 inches. The illustration shows the true pitch of the common rafter, with a run of 12 inches and a rise of 10 inches, and the true pitch of the hip rafter corresponding to this pitch.

JACK-RAFTERS

11. Laying Out Jack-Rafters.—The foot- and the plumb-cuts of jack-rafters are the same as those for common rafters. Jack-rafters differ from common rafters, however, in that a side, or cheek, cut is required at the top of a jack-rafter, in order to make it fit against the hip or valley rafter. In order to obtain this cut, take the run of the common rafter on the tongue of the square and the length on the body of the square and cut along the body.



(a) (b)

Fig. 8

In a $\frac{1}{3}$-pitch roof, the run is 12 inches, and the length of the common rafter per foot of run is $14\frac{7}{16}$ inches; consequently, by taking 12 inches on the tongue and $14\frac{7}{16}$ inches on the body and cutting along the body, the cheek cut will be found.

In Fig. 8 (*a*) is shown the application of the square at the top edge of a jack-rafter to obtain this cut, while in (*b*) is shown the square applied to the side of the jack-rafter, in order to get the foot- and the plumb-cuts.

12. To find the difference in the lengths of jack-rafters, multiply the length, in feet, of the common rafter per foot of run by the distance, in feet, between centers; subtract this product from the length of the common rafter, and it will give the length of the first jack-rafter or the one next to the common rafter. This same difference subtracted from the first jack-rafter will give the length of the second jack-rafter.

If, on a $\frac{1}{3}$-pitch roof, the jack-rafters are spaced on 2-foot centers, multiply the length of the common rafter per foot of run by 2; thus, $14\frac{7}{16} \times 2 = 28\frac{7}{8}$ inches, or 2 feet $4\frac{7}{8}$ inches, which is the difference in length for all jack-rafters on a $\frac{1}{3}$-pitch roof, where the rafters are spaced 2 feet apart from center to center.

The length of the common rafter in Fig. 6 (*a*) is 16 feet 11 inches. Then, by subtracting 2 feet $4\frac{7}{8}$ inches from the length of the common rafters, the length of the first jack-rafter will be obtained; thus, 16 feet 11 inches − 2 feet $4\frac{7}{8}$ inches = 14 feet $6\frac{1}{8}$ inches. Or, if the jack-rafters are started from the bottom of the hip, the first one will be 2 feet $4\frac{7}{8}$ inches long; the next, 2 feet $4\frac{7}{8}$ inches + 2 feet $4\frac{7}{8}$ inches = 4 feet $9\frac{3}{4}$ inches long; and each one thereafter will increase 2 feet $4\frac{7}{8}$ inches in length for each 2 feet they are spaced. If the jack-rafters are spaced 16 inches on centers, multiply the length of the common rafter per foot of run by $1\frac{1}{3}$ feet, or, expressed decimally, 1.333 feet. This method applies to any pitch.

To find the length of a roof timber multiply the bridge measure per foot of run by the run of the common rafter.

METHODS OF FRAMING

13. Reducing Run and Rise to Inches.—Fig. 9 represents a plan and elevation of a hipped roof of equal pitch, having a run of 15 feet and a rise of 9 feet. To find the figures on the square to obtain the foot- and the plumb-cuts of the common rafter, the run and the rise are first reduced to inches. Thus, the run will be 15 × 12 = 180 inches, and the rise will be 9 × 12 = 108 inches. As these figures are beyond the limits of the square, it will be necessary to reduce them, which is done by dividing each number by the same divisor. Assuming 12 for the divisor, 180 ÷ 12 = 15 for the run, and 108 ÷ 12 = 9 for the rise. By taking *15* on the body of the square and *9* on the tongue of the square and cutting along the body, the foot-cut will be obtained, and by cutting along the tongue the plumb-cut will be obtained.

14. To obtain the length of the rafter, it will be necessary to step twelve times along the rafter timber, or to multiply the bridge measure of 15 and 9 by 12. The rule is to step as many times as the number used for the divisor. Any figure may be used for a divisor, provided it will reduce the run and the rise to figures within the limits of the square. If 9 is chosen as the divisor, 180 ÷ 9 = 20 and 108 ÷ 9 = 12, thus obtaining 20 inches for the run and 12 inches for the rise. The *20* on the body of the square gives the foot-cut and the *12* on the tongue gives the plumb-cut. To get the length of the rafter, multiply the bridge measure of 20 and 12 by 9, as 9 was the divisor.

15. Hip- and Valley-Rafter Cuts.—The cuts and lengths of hip rafters and valley rafters are found by the operation just described. For a roof of equal pitch, the plan lines of the hip or valley are in a known proportion to the plan lines of the common rafter. This proportion may be expressed by a rule as follows:

Rule.—*The run of the common rafter is to the run of the hip or the valley rafter as 12 is to 17; that is, for every foot of run of the common rafter, the hip or the valley rafter will be 17 inches.*

Thus, the plan lines of the hips in Fig. 9 will measure 21 feet 3 inches. To find the foot- and the plumb-cuts of the hip rafter, reduce the 21 feet 3 inches to inches, which equals 255 inches. The rise of 9 feet is equal to 108 inches. Reducing these figures to the limits of the square by dividing by 12, gives a run of 21¼ and a rise of 9 inches; then, 21¼ inches on the body of the square will give the foot-cut and 9 inches on the tongue will give the plumb-cut. To obtain the length of the hip rafter, step along the timber twelve times, or multiply the bridge measure of 21¼ and 9 by 12.

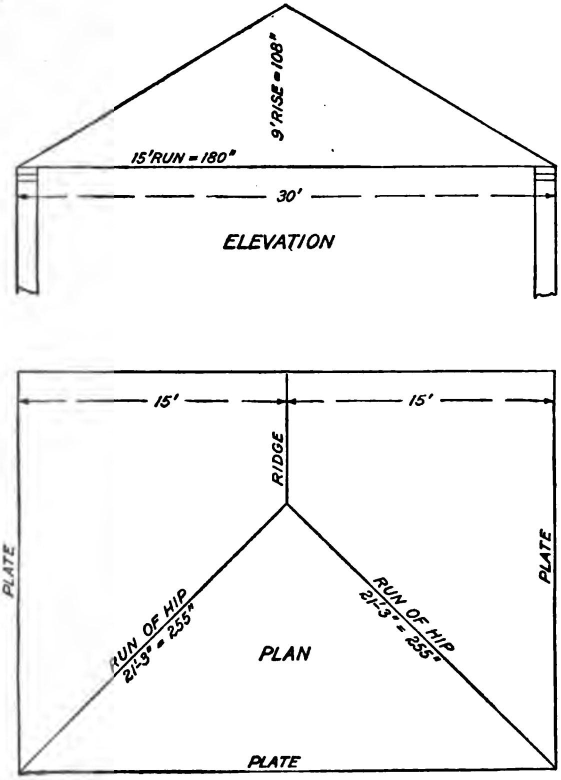


FIG. 9

16. Five-Inch Method.—The 5-inch method of laying out rafter timbers is applicable only to ½-pitch roofs. With this method, the lengths of all roof members may be found by adding 5 inches to each foot of run, as scaled from the plan lines. Fig. 10 shows the plan of a roof with three gables and two valleys, the pitch of the common rafters being 12 inches rise for each foot of run, or a ½ pitch. The plan lines of the common rafters are 12 feet; consequently, by adding 5 inches twelve times to the run of the common rafter, the length of this rafter will be found. Thus, 5 × 12 = 60 inches, or 5 feet, and 12 + 5 = 17 feet, which is the length of the rafter.

To find the cuts, take *12* on the body and *12* on the tongue, and apply the square to each end of the rafter.

To find the length of the valley, add 5 inches to each foot of its 17-foot run. Thus, 17 × 5 = 85 inches, or 7 feet 1 inch; adding this result to 17 feet will give 24 feet 1 inch for the length of the valley. Measure this length along the valley timber, and at each end apply the square with *17* on the body and *12* on the tongue; the body will give the foot-cut and the tongue will give the plumb-cut.

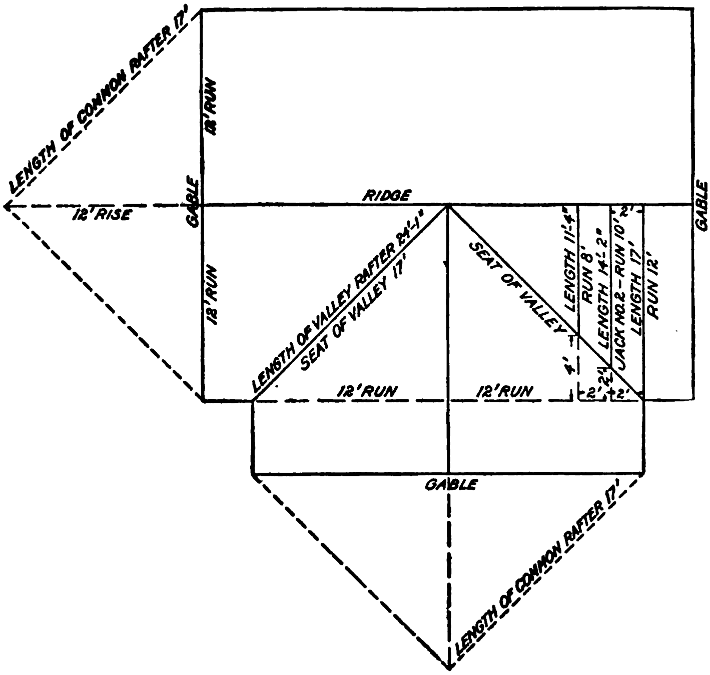


Fig. 10

17. The length of all the jack-rafters may be determined by the foregoing process. The jack-rafters in Fig. 10 are placed 2 feet from center to center; consequently, jack-rafter *No. 2* is 2 feet shorter in plan than the common rafter, thus making the run of this jack-rafter 10 feet. Now, by adding 5 inches for each foot of run, the length of the jack-rafter will be obtained. Thus, 10 × 5 = 50 inches, or 4 feet 2 inches; adding this distance to the run of the jack-rafter gives 14 feet 2 inches, which is therefore the length of jack-rafter *No. 2*. The length of the next jack-rafter will be 2 feet 10 inches shorter, or 11 feet 4 inches.

18. Roof Framing From Plan Lines.—Fig. 11 illustrates **the plan lines** of a hip-and-valley roof of equal pitch,

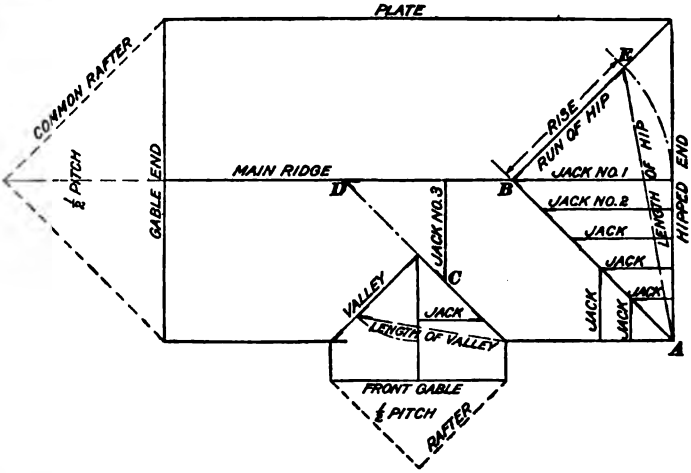


FIG. 11

these lines showing the foot- and the plumb-cuts and the lengths of all the rafters. The method of framing from plan lines can be applied only to roofs of ½ pitch, but as this pitch is probably used more extensively than any other, a knowledge of the method may prove of value. The plan of the roof is usually drawn to a large scale, 1½ inches to the foot making a convenient scale, as each ⅛ inch on the scale will equal 1 inch on the roof.

19. In Fig. 11 are shown two hips on the right side of the building, while on the left are shown two rafters of the wide gable. The length of these rafters is equal to the plan lines of the hips. The dotted lines on the left are an elevation of the common rafters, and, as will be observed, these lines and the angles they make with each other are the same as the plan lines of the hipped end; therefore, the construction of an elevation is not necessary.

The length of the common rafter may be found by scaling the plan lines of the hips; or, in other words, the run of the hip is equal to the length of the common rafter. The same is true of the rafters and plan lines of the valleys in the front gable.

20. The similarity of lengths and of angles between common rafters and hip rafters or between common rafters and valley rafters is the fundamental principle underlying the method of framing from plan lines. As the run of the hip has the same length as the common rafter, it is quite evident that the angle that jack-rafter *No. 1*, Fig. 11, forms with the run of the hip will be the plumb-cut, and the angle that the run of the hip makes with the end plates will be the foot-cut.

The angles of jack-rafters, where they intersect hip rafters or valley rafters, are equal to 45°, and by taking 12 inches on both the body and the tongue of the square, the plumb- and the foot-cuts can be obtained.

The jack-rafters may also be laid out on this same principle. Space the jack-rafters as shown—jack *No. 1*, jack *No. 2*, etc. By scaling the plan line of the hip from *A* to *B*, the length of jack-rafter *No. 1* will be found. This jack-rafter is equal in length to the common rafter, and the plumb- and the foot-cuts are the same as for the common rafter.

By scaling the plan line of the hip from *A* to the end of jack-rafter *No. 2*, the length of the latter can be found. The same process of scaling the plan line of the hip will give the exact length of all the other jack-rafters.

The plan line of jack-rafter *No. 3* is shown at *C*. To lay out this rafter, continue the plan line of the valley until it intersects the main ridge; then *CD* will be the length of jack-rafter *No. 3*.

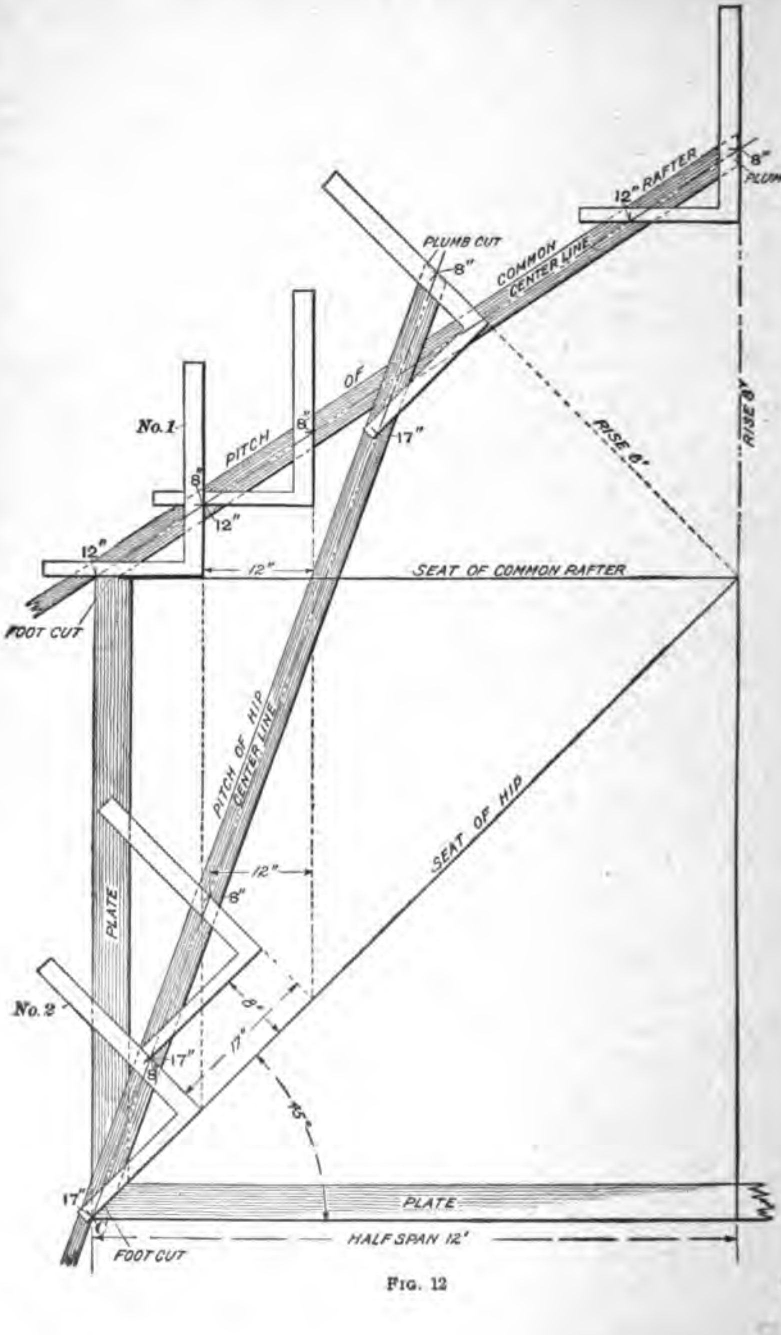

8"
12" RAFTER
PLUMB CUT
PLUMB CUT
8"
COMMON
CENTER LINE
OF
No. 1
PITCH
8"
17"
RISE 8"
RISE 8"
8"
12"
12"
12"
SEAT OF COMMON RAFTER
FOOT CUT
PITCH OF HIP
CENTER LINE
SEAT OF HIP
PLATE
12"
8"
No. 2
8"
17"
8
17"
45°
17"
PLATE
C
FOOT CUT
HALF SPAN 12'

FIG. 12

21. To lay out the hip, the plan line of jack-rafter *No. 1* is revolved to *E*, a point on the plan line of the hip. *E* is then connected with *A*, and *EA* is the length of the hip rafter. *BE* is equal to the rise, or the distance that the main ridge is above the plates.

The same process is shown applied to the valley of the front gable. The angles that these lines form with the plan lines of the two hips and the two valleys define the foot- and the plumb-cuts. The figures to be used on the square to lay out the cuts for the hips and valleys, are *12* on the tongue and *17* on the body, the tongue giving the plumb-cut and the body the foot-cut.

22. To Lay Out a Hip or Valley for Equal-Pitch Roofs.—In roofs of equal pitch, the seat of the hip or the valley stands at an angle of 45° with the plates of the building, as shown in Fig. 12. In this figure, the run of rafter is 12 feet, while the rise is 8 feet, thus making the roof ⅓ pitch. The figures to be used on the square to get the plumb- and foot-cuts are *12* on the tongue and *8* on the body, as shown by the application of square *No. 1* to the pitch of the rafter. By drawing a vertical line from the heel of square *No. 1* to intersect the seat of the hip, and placing the heel of square *No. 2* at the point of intersection, it will be found that *17* on the tongue will come to the corner *C* of the building, thus showing that a 12-inch run on the common rafter is equal to a 17-inch run on the hip or valley.

Square *No. 1* shows a 12-inch run to an 8-inch rise for the common rafter, and square *No. 2* shows a 17-inch run to an 8-inch rise for the hip. The figures *17* and *8* are to be used on the square when laying out the hip rafter or valley rafter, as the case may be. It should be remembered, however, that these figures apply only to hips and valleys on equal pitch roofs. In all roofs of this description and of any pitch, provided the pitches are equal, *17* on the tongue of the square and the rise per foot of run of common rafter on the body of the square will be the figures to use for the foot- and plumb-cuts. For the length of the rafter, it will be necessary to step along the timber the same number of times as for the common rafter.

23. Jack-Rafters and Roof Boards for a Hip or Valley Roof.—In Fig. 13, $ABCD$ represents the plan of one end of a hipped roof. AE and BE are the seats of the hip; DE and EC, the runs of the common rafters; EF, the rise of the roof; and DF, the length of the common rafter. Erect a perpendicular to the seat of the hip at E, and revolve F to G; or, in other words, make EG the same length as EF. Connect A and G; then, AG will represent the length of the hip. Next, make AH and BH equal to AG; then, the triangle AHB will be the true size and shape of the end roof. Or, assuming that the triangle AEB is hinged at AB and that the point E is revolved so that the triangle AEB will lie flat, or in a horizontal position, then the point E will drop

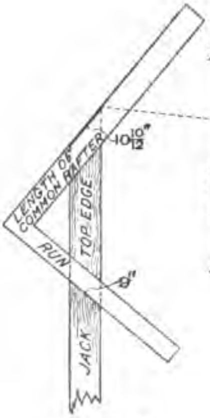


FIG. 14

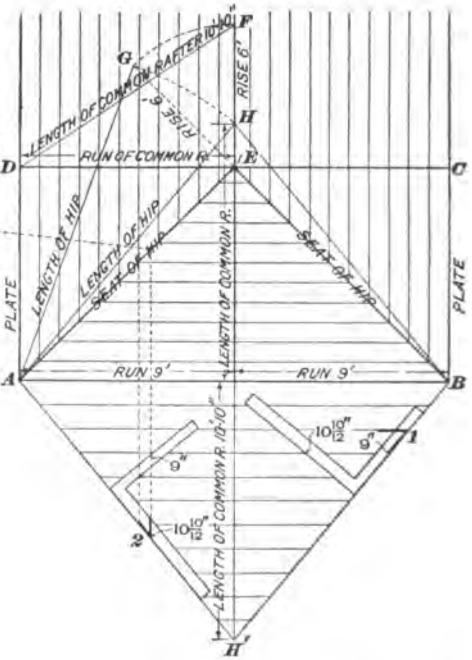


FIG. 13

to *H*; again, if the roof is revolved in an opposite direction, the point *E* will revolve to *H'*, and triangles *A H B* and *A H' B* will be equal in every respect.

The roof in the position *A H' B* shows the true lengths and true angles, and, consequently, when in this position, the square or bevel can be laid on any piece and the true angle taken. Thus, the bevels at *1* and *2* are the true angles that the roof boards and jack-rafters make at the hips.

24. In any right triangle in which the true lengths of all the sides are shown, the figures to use on the square to cut any piece to fit the sides or angles may be obtained by taking the length of two of the sides, provided that the piece is parallel with one of the sides. Thus, for the side cut of the jack-rafter, one side of the triangle is 9 feet and the other is 10 feet 10 inches, the former being the run and the latter the length of the common rafter. Then, by taking 9 feet on the tongue and 10 feet 10 inches on the body, and cutting along the body of the square, the side cut of the jack-rafter will be obtained. In order to get these figures within the limits of the square, it is necessary to reduce the figures by dividing each side by the same number. In this case, the divisor will be 12, which is the same as calling the feet inches. Then, take 9 inches on the tongue of the square and $10\frac{10}{12}$ inches on the body of the square, and cut along the body.

From the foregoing explanation, the following rule for the side, or cheek, cut of jack-rafters is deduced:

Rule.—*To find the cheek cut for jack-rafters, take 12 inches on the tongue of the square, and the length of common rafter per foot of run on body of the square and cut along the body.*

25. Fig. 14 illustrates the application of the square to the top edge of a jack-rafter. The plumb-cut of the jack-rafter will be the same as the plumb-cut for the common rafter.

26. On account of the roof boards being at right angles to the jack-rafters, the face cut will be the same as the cheek cut of the jack-rafters, except that the cut is made along the tongue of the square. Fig. 15 (*a*) shows the square applied to the face of the board, while (*b*) shows the figures to use if the roof board is to be mitered so as to make a tight joint at hip or valley.

27. Purlins and Roof Boards.—In Fig. 16 (*a*) is shown part of the plan of a hipped roof with purlins and roof boards in place. Above the plan is shown the elevation of the common rafters, and a section of the purlin and a roof board. In (*b*) is shown a method of obtaining the face cut and miter cut for either the purlins or the roof boards.

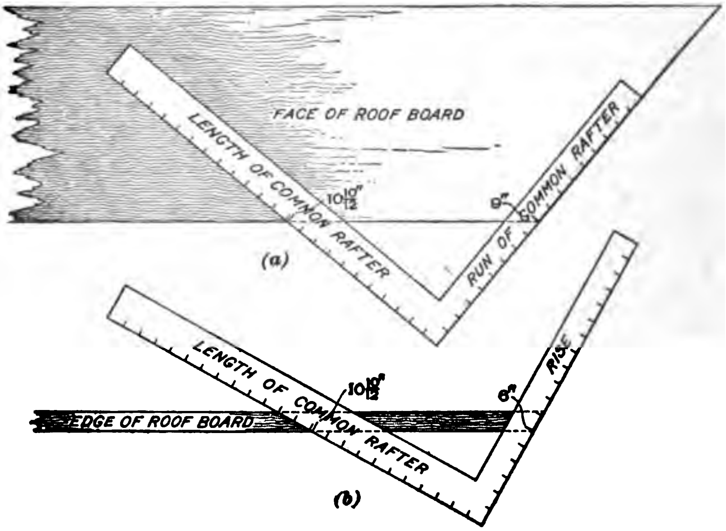


Fig. 15

The line *A C* represents the length and pitch of the common rafters; *A B*, the run of the common rafters; and *B C*, the rise of the roof. Take *A* as a center and the run *A B* as a radius, and describe the arc *D B E*, cutting the rafter line in *D* and the line *A F* (which is drawn at right angles to *A C* through *A*) in *E*. Connect *C E* and *F D*, and the angle at *D* will be the miter angle for either the purlin or the roof board, and the angle at *E* will be the face angle.

It will be observed that the results are the same as were obtained in Fig. 13, the roof having the same pitch. This method is limited to equal-pitch roofs, but not to any special pitch. If a 45° pitch had been illustrated, the miter and face bevel angles would have been equal.

This method may also be applied to hoppers or any other work where the jambs and heads are splayed, such as doors, windows, etc.

28. Seat Cut for Hip or Valley.—The following method may be used to lay out the seat cut of a hip rafter or a valley rafter so that the top edge of the rafter—backed or not backed—will be in the same planes as the intersecting roofs. As the hip or valley is placed diagonally to the plates of the building, and the pitch is different than the pitch of the common rafter, there will be a difference in the foot-cuts. At *a*, Fig. 17, is shown the plan lines of a hip or valley intersecting the plates of one corner of a building. In this illustration are also shown the pitch of the common rafter, the hip rafter, and the valley

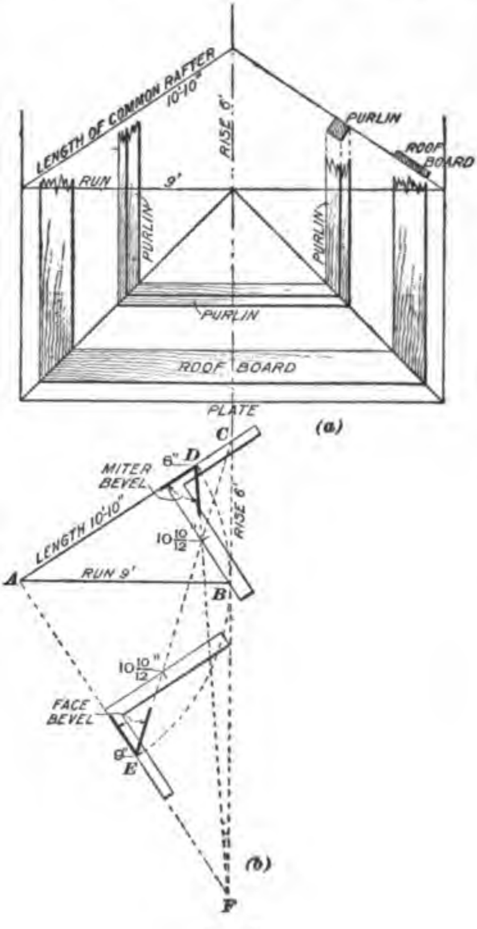


FIG. 16

rafter. It will be noted that the common rafter has a ½ pitch, and that the figures on the square for this pitch are *12* and *12*, while the figures for the corresponding hip and valley rafters are *17* and *12*.

29. Fig. 17 also illustrates the method of determining the thickness of the hip or the valley rafter above the plate, to correspond with the thickness of the common rafter. If a hip is to be laid out, its plan lines will intersect the plates at *M* and *N*, while a valley will intersect the plates at *O* and *P*. Lay off *MW* and *WS* equal to one-half the thickness of the hip or the valley timber. Through *W* and *S* draw lines parallel with the plates. Let *AB* represent the thickness of the common rafter above the plates; then, the problem is to find the relative thickness of the hip or valley. For a hip, it will be noticed that the same thickness as that of a common rafter will do, if the hip is not backed, as shown at *GH*, but the foot-cut must be extended to the line *W*, as shown at *ED*. If it is backed, *ED* represents the thickness.

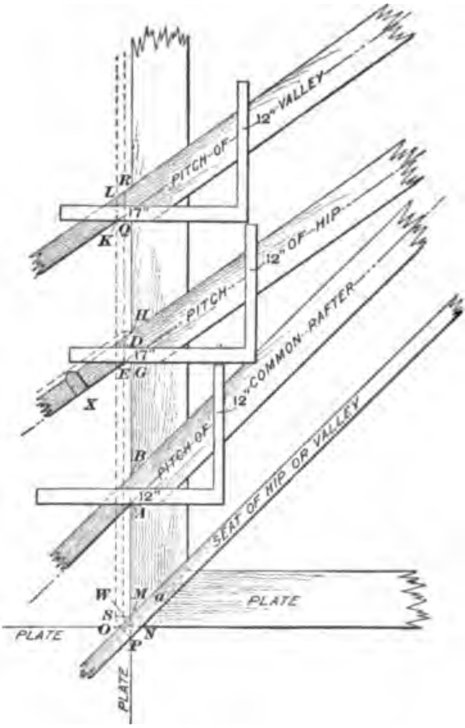


Fig. 17

The thickness of the valley is shown at *QR*, and is the same as that of the common rafter, backed or not backed, but the foot-cut must be extended to *KL*. A rafter is backed when the upper corners are dressed off to the center of the rafter on either side, so that the top edge will be in the same plane as the roof on both sides of the rafter. The backing of a hip rafter is shown in section at *X* in the illustration.

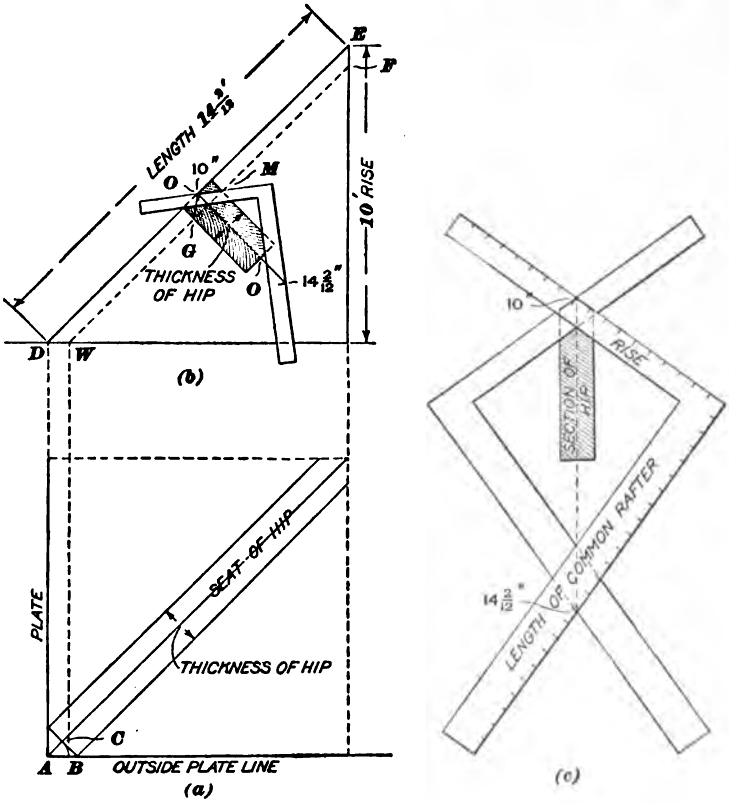


FIG. 18

30. Backing Hip or Valley Rafters.—The following method explains how to find the figures on a square to back a hip or a valley rafter. In Fig. 18 (*a*) is shown the plan lines of one corner of a hip roof, while in (*b*) is shown the elevation of the common rafter, *DE* being the pitch of the rafter. Revolve the point *C* to *B*, which makes *AB* equal to one-half the thickness of the hip. Through *B*, draw the line *B W* parallel with the plate, and from *W* draw a line *WF* parallel with the pitch of the rafter. At any point on the rafter draw a section of the hip at right angles to the rafter. Through the center of the section, draw the line *O O*; connect *O* and *G*, and *O* and *M*; then, *O G* and *O M* will define the backing. The triangular pieces above the lines *O G* and *O M* are to be removed from the hip rafter. The figures to use on the square to obtain the cuts are the length of the rafter on the body of the square and the rise of the rafter on the tongue of the square. The cut will be along the tongue.

In (*b*) the square is shown applied to the rafter timber, and in (*c*) the square is shown applied to both sides of the hip rafter. If a bevel instrument is used, the bevel may be set on the square, clamped to hold its position, and the angle then transferred to the hip timber.

EXAMPLES OF ROOF FRAMING

FRAMING AN EQUAL-PITCH ROOF

31. A complete plan of a hip-and-valley roof of equal pitch is shown in Fig. 19. This is a representative plan of the better class of roofs for a residence, and contains a variety of rafters, hips, valleys, and jack-rafters. The width of the front gable is 16 feet; that of the left-side gable, 12 feet 6 inches; and that of the rear gable, 10 feet. The span of the main roof is 22 feet.

The front gable rafters rise 8 feet and have a run of 8 feet, which is a rise of 12 inches per foot of run. For the foot- and the plumb-cuts, take 12 inches on the tongue for the run and 12 inches on the body for the rise. The tongue gives the foot-cut, and the body, the plumb-cut. For the length of the rafter, step eight times along the rafter timber. If the ridge pole is 1 inch thick, ½ inch is to be cut from the length obtained by stepping. The length as now found will reach from the plumb-face of the plate to the plumb-face of the ridge pole.

32. To lay out the foot-cut proceed as shown in Fig. 20. Point *A* in this illustration represents the length as found by stepping eight times along the rafter timber from the ridge point, and is therefore plumb above the face of the wall plate. Place the square with 12 inches on the tongue and 12 inches on the body, as shown by square *No. 1*. From the upper side of the rafter, shown at *A B*, gauge the line *CD* at a distance equal to the thickness of the projecting part of the rafter, designed to support the cornice, beyond the

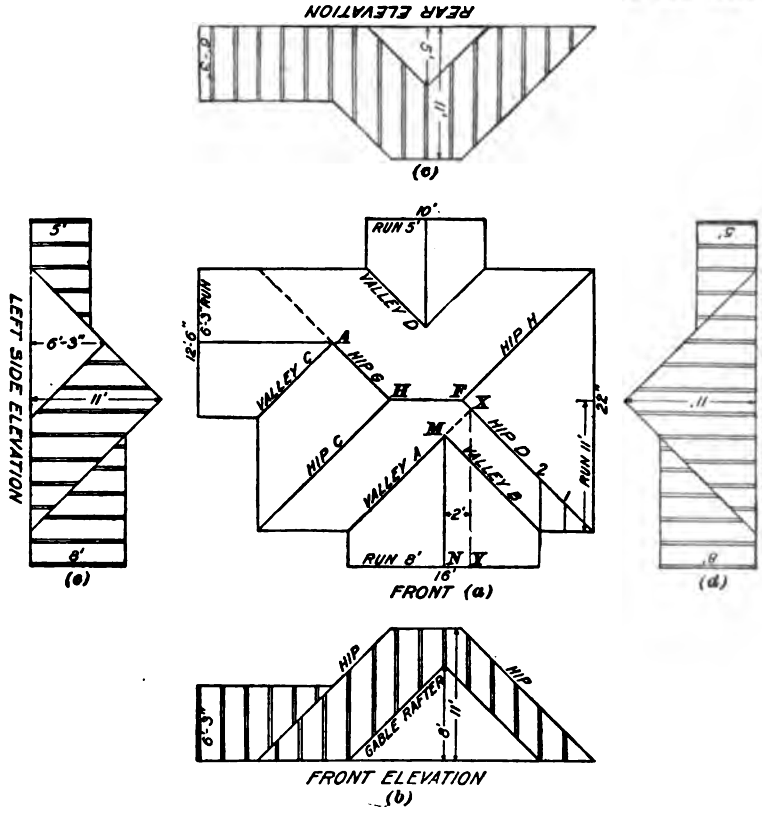


FIG. 19

wall plate. The line *CD* will intersect the tongue of square *No. 1* at *C*. Place the square at this point, as shown by square *No. 2*, and draw the line *CE*, which will be the foot-cut of the rafter.

This completes the laying out of the rafter. The remaining rafters for the front gable may be cut by using the foot-cut just found as a templet, or pattern.

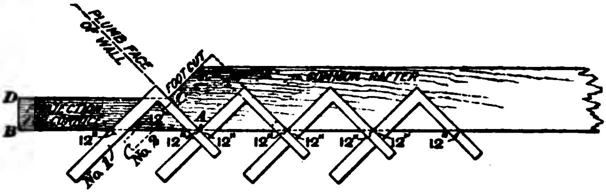


Fig. 20

33. The rear gable rafter can next be laid out, and as the pitch is equal throughout the room, the same figures on the square are to be used to obtain the foot- and plumb-cuts. That is to say, the figures on the square that should be used are 12 inches on the tongue and 12 inches on the body. To obtain the length of the rafter, it will be necessary to step five times along the rafter timber, owing to the run being 5 feet. The operation of laying out the foot-cut is the same as that employed for the front gable rafter.

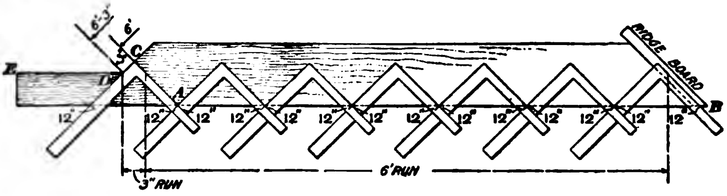


Fig. 21

34. The span of the left-side gable is 12 feet 6 inches; the run of the rafter, therefore, is 6 feet 3 inches. As the run of this rafter contains a fraction of a foot, the method of obtaining the length will be slightly different than that employed in laying out the rafters for the rear gable. Place the square on the rafter timber as before, with 12 inches on the tongue and 12 inches on its body, and step along the timber six times, to determine the length for a 6-foot run.

To add the fractional part, 3 inches, proceed as shown in Fig. 21. The point *A* is the length found by stepping six times from the plumb-cut at *B*. Lay on the square at *A* as for another step, and from the heel *C* measure 3 inches along the body, as shown at *D*. Gauge the line *DE* the thickness of the projecting portion of the rafter beyond the plate, and draw the foot-cut along the tongue line through *D*, as shown.

35. The plan, Fig. 19 (*a*), shows that the four hips are of equal length, except that hip *G* is cut at a point where it intersects the ridge of the left-side gable. It is considered better construction if the hip is not made continuous from the ridge to the plate, as shown by the dotted line. If the hip were continued, it would be necessary to cut all the jack-rafters on the rear slope that run from the ridge to the rear plate. By cutting the hip off at the ridge, however, it affords a clean space from the plate to the dormer ridge, as shown in the rear elevation (*c*).

To lay out the long hip *H*, Fig. 19 (*a*), proceed by applying the square to the hip timber, with *17* on the tongue and *12* on the body; the tongue will give the foot-cut and the body will give the plumb-cut. To obtain the length of the rafter, it will be necessary to know the run of the rafter that spans from the plate to the ridge. The run of the rafter in this case is 11 feet. Place the square on the hip timber with *17* on the tongue and *12* on the body, and step eleven times; this will give the length of the rafter from the plate to the ridge.

It will be necessary to lay out the foot-cut, as in the case of the common rafter, but in order to do so the height that the hip is to be above the plate must be known, so that it can be made to coincide with the height above the plate of the common rafter. Referring to Fig. 22, which represents a corner of a building containing the lines of the plates and the seat of the hip, it will be seen that the seat of the hip relative to the plate extends from *C* to *A*, and that the upper end of the hip, provided it is not backed, will coincide with the line *D E*, which is a square line to *A C* drawn through *A*.

Referring now to Fig. 23, assume that the illustration represents the lower end of the hip rafter and that the point *D* is plumb with the plate. From point *D*, place square *No. 1* in the position shown as if about to measure the rafter by stepping, using *17* on the body and *12* on the tongue. Make *A D* one-half the thickness of the hip rafter, which is equal to *A D*, Fig. 22, and make *D F* equal to the thickness of the common rafter above the plate. As will be noticed, *D F* also represents the thickness of the hip at the point where it intersects the plate, as shown at *G H*, Fig. 22, but as the hip is to extend to point *A*, Fig. 22, its thickness at this point is shown in Fig. 23 to be *A E*.

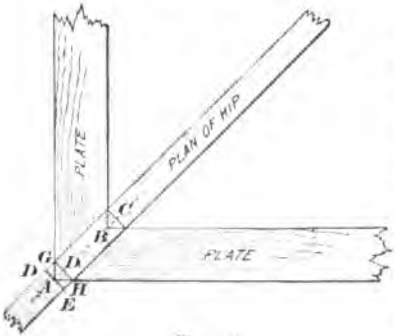


Fig. 22

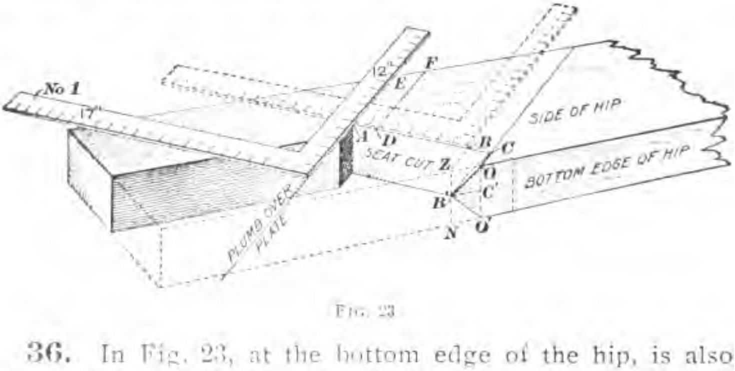


Fig. 23

36. In Fig. 23, at the bottom edge of the hip, is also shown the method of treating the bottom edge if a close fit against the plates is desired. It will be noticed that *A D B C* on the seat cut, Fig. 23, is equal to *A D B C*, Fig. 22. From *B*, Fig. 23, draw *B Z*, and from *C* draw *C O*; also draw the lines *OCO'* and *ZB'N* square across the bottom of the timber. Connect *B'* and *O*, and *B'* and *O'*; then, cutting along these last two lines will frame the hip to fit against the plates at the internal angle *B*, shown in plan in Fig. 22. This hip is now complete, and may be used as a templet to lay out hips *D* and *C*, Fig. 19 (*a*).

37. To lay out hip *G*, which is shown in Fig. 19 (*a*), take 17 inches on the tongue and 12 inches on the body of the square, as was done in laying out the other hips. Step along the timber four times, and add 9 inches for the fractional part of a foot that the run contains. The run of the hip *G* can be found by taking the run of the main roof, which is 11 feet, and the run of the gable rafter, which is 6 feet 3 inches, and then deducting the 6 feet 3 inches from 11 feet, which gives 4 feet 9 inches.

To lay out the rafter for this run, take *12* on the tongue and *12* on the body of the square and step four times along the rafter timber, completing the operation by adding 9 inches by the method illustrated in Fig. 21.

To lay out the hip, follow the method illustrated in Fig. 23. Having found the length of the hip rafter, the plumb-cut is found by marking along the side of the square that gives the rise. As this hip butts against the side of the ridge of the left-side gable, as shown at *A*, Fig. 19 (*a*), the foot-cut also will be found by marking along the rise. It will be noticed that both cuts are plumb, the top cut butting plumb against the side of the main ridge, as shown at *H*, Fig. 19 (*a*), and the bottom cut butting plumb against the side of the left-side gable ridge.

The cheek bevel of the hip to fit against the main ridge, shown at *H*, is obtained by taking the length of the rafter on the tongue and the run of the rafter on the body of the square, and marking along the tongue for the cut. The cheek cut for the abutment at *A*, if framed to fit against the ridge of the left gable, will be the same as that for the main ridge at *H*; but, if the abutment is framed to fit against the valley *C*, it will be a square cut from the side of hip.

38. To lay out valley *C*, which is shown in Fig. 19 (*a*), spanning from the plate to the hip *G*, take *17* on the body and *12* on the tongue and mark along the body for the foot-cut and along the tongue for the plumb-cut. To obtain the length of the rafter, step along the valley timber six times and then add the 3 inches of run by the method shown in Fig. 23. The number of steppings for this valley is regulated by the run of the left-side gable rafter, which is 6 feet 3 inches. The cheek cut will be square across the back, so as to butt against the side of hip *G*.

39. To lay out the valley of the rear gable, Fig. 19 (*a*), marked valley *D*, use *17* on the body and *12* on the tongue for the foot- and plumb-cuts. As the run of the rear gable is 5 feet, it will be necessary to step five times along the valley timber to obtain the length. To frame the rafter so that the cheek cut will fit against the ridge of the rear gable, take the length of the gable rafter on the body and the run on the tongue and mark along the body for the cut.

40. To lay out valley *A* of the front gable, Fig. 19 (*a*), use *17* on the body and *12* on the tongue for the foot- and plumb-cuts. It will be noticed that valley *A* extends beyond the ridge of the front gable to the point marked *X*, and that it butts against the long hip *D*; therefore, this valley rafter will be the distance *MX* longer than its opposite valley *B*.

From *X*, drop a perpendicular line to the plates on the front gable at *Y*. Measure the distance from *Y* to the ridge at *N*, and add this distance to the 8 feet, which will give the total length of run of the valley rafter *A*. Assume that the run of the valley rafter is 10 feet; then, from this data, valley *A* may be laid out. Take *17* on the body of the square and *12* on the tongue of the square and step along the valley timber ten times, marking along the body for the foot-cut and along the tongue for the plumb-cut. The cheek cut to fit against the long hip at *X* will be a square cut across the back of the hip.

41. Valley *B* is shown to span from the plate to *M*, a point where the ridge of the front gable intersects valleys *A* and *B*. To lay out valley *B*, take *17* on the body and *12* on the tongue and step along the valley timber eight times for the length. The cheek cut at *M* to fit against valley *A* will be a square cut.

42. To obtain the cuts for the jack-rafters, use the same figures on the square as for the common rafters; namely, *12* on the tongue and *12* on the body. The relative difference in length may be determined by the operation shown in Fig. 24, where square *No. 1* is shown placed on the jack-rafter timber with *12* on the body and *12* on the tongue. If 18 inches is determined on for the spacing between centers of jack-rafters, slide the square along the line of tongue 6 inches. The square will then be in the position shown by square *No. 2*; the heel will be at *A*, and both the body and the tongue will have the figures *18* where they intersect the side of timber.

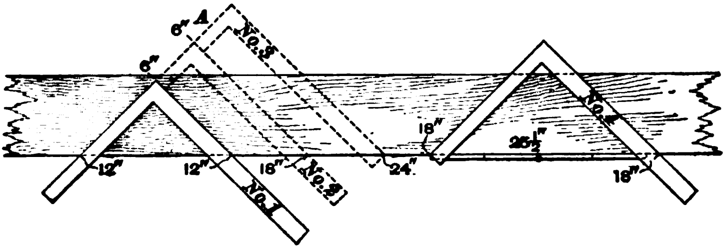


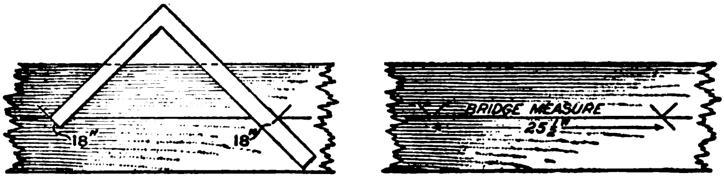
FIG. 24

By measuring with a 2-foot rule across the square from *18* on the body to *18* on the tongue, as shown at square *No. 4*, the distance will be found to be 25½ inches, which is the length of the shortest jack-rafter. Twice this length will be the length of the second jack-rafter, three times will be the length of the third, and so on.

The bridge measurement from *18* to *18* on the square may be taken more accurately by laying the square on a board, and then, by means of a knife, marking at right angles to the edges of the square and along the edges, as shown in Fig. 25 (*a*). At (*b*) is shown the board with the square removed. By measuring in this way, the marks on the board and the edges of the square are more sharply defined.

If the jack-rafters are to be placed 2 feet from center to center, the square will have to be put in the position shown by square *No. 3*, Fig. 24. The bridge measure will then be 34 inches, which will represent the length of the shortest jack-rafter. The rule is to slide the square so that the body will measure the distance that the jack-rafters are placed apart.

To find the cheek cut for the jack-rafters, so that they will fit against the sides of hips or valleys, take the length of the common rafter on the body and the run of rafter on the tongue and mark along the body of the square for the cut.



(a) (b)

FIG. 25

Instead of the foregoing method, the cheek cut for a jack-rafter can be obtained by taking the length of the common rafter per foot of run on the body and 12 inches on the tongue and cutting along the body.

FRAMING AN UNEQUAL-PITCH ROOF

43. In the roofs thus far described, all the pitches of the several surfaces composing the same roof have been similar. Such roofs are called **equal-pitch roofs.** In **unequal-pitch roofs,** or those in which the several surfaces have two or more pitches, however, the square must be manipulated in a different manner when laying out the several rafters, which is due to the fact that all the runs and all the rises are not proportional. The elevation of all the ridges in the several parts of a roof may be the same, but the width of the several wings and bays may be different; consequently, the rafters would have different runs. Again, all the runs may be alike, but the rises different; or, all the runs and all the rises may be different. Any of these conditions will form an unequal-pitch roof.

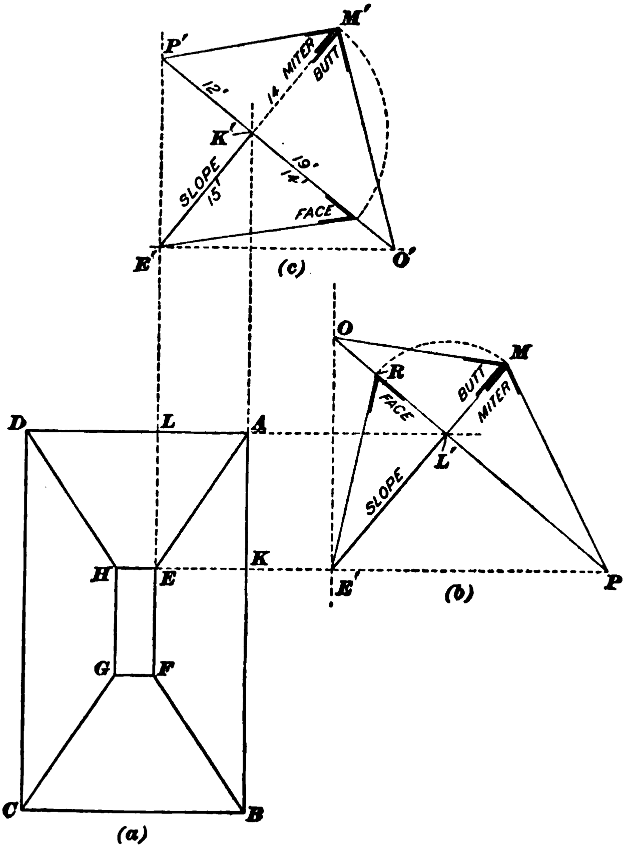


FIG. 26

44. Analyses of Hoppers.—Before describing unequal-pitch roofs, it may be well to analyze hoppers of unequal pitch, and then turn the hopper over, or upside down, and compare it with a roof. It will be found that the figures on the square to obtain the cuts for hoppers are identical with those used to obtain roof cuts of equal angles.

Fig. 26 (*a*) shows the plan of a hopper of unequal pitch, A, B, C, and D being the top edges of the hopper, and E, F, G, and H, the bottom edges, or discharge side, of the hopper. The lines AE, BF, CG, and DH are the plan lines of the intersection of the sides and ends of the hopper, while EK is the plan width of one side and EL the plan width of one end.

45. In Fig. 26 (*b*) is shown the method of obtaining the cuts for the end pieces. Project the points LE at right angles to AB, in (*a*), and, from some point, as E', draw a line $E'L'$ at the desired pitch; this line will then represent the true length of EL. From L' and at right angles to $E'L'$, draw the line OP; produce the line $E'L'$ to M, making $L'M$ equal to EK, or the run of the side of the hopper. From M draw MP and MO; then, the angle $L'MP$ will be the miter bevel, or the bevel across the edge of the board, and $L'MO$ will be the butt bevel.

For the face bevel, or cut across the width of the board, make $L'R$ equal to $L'M$, and connect $E'R$; then, the angle $E'RL'$ will be the correct bevel to use.

46. In (*c*) is shown the method of getting the angles for the side pieces of the hopper. It will be noticed that the construction is the same as for the end. $E'K'$ is the true length and slope of the side EK, and $K'M'$ is equal to LE, or the run of the end. The miter butt and face cut are shown.

To find the figures on the square that will give the cuts, scale the distances $E'K'$, $K'P'$, $k'M'$, and $K'O'$. Assume that these distances scale 15, 12, 14, and 19, respectively, calling them either inches or feet. Then, for the miter cut, take 12 inches on the body of the square and 14 inches on the tongue of the square, and cut along the tongue; for the butt cut, take 19 inches on the body and 14 inches on the tongue, and cut along the tongue; for the face cut, take 15 inches on the body and 14 inches on the tongue, and cut along the tongue. The cuts of the ends may be obtained in the same way.

47. Comparison of Hoppers and Roofs.—The foregoing method, as applied to a hip-and-deck roof, is shown in Fig. 27, in which *A*, *B*, *C*, and *D*, in (*a*), represent the plates, and *E*, *F*, *G*, and *H*, the ridges. *AE*, *BF*, *CG*, and *DH* are the hips; *EK*, the run of the common rafter on the narrow side; and *EL*, the run of the common rafter on the end. In (*b*), *L′E′* is the pitch of the common rafter on the ends, and in (*c*), *K′E′* is the pitch of the common rafter on the narrow side.

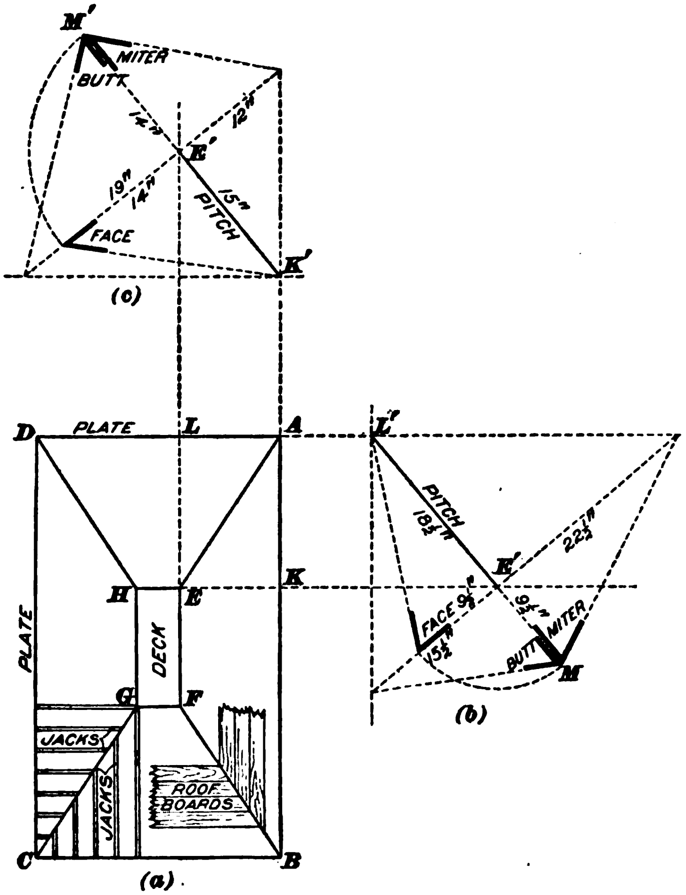


FIG. 27

It will be observed that the construction in Fig. 27 (*b*) and (*c*) is the same as that in Fig. 26 (*b*) and (*c*), with the exception that the pitch in the roof timber is in a different direction than the slope of the sides of the hopper. The several pitches of the roof and the various slopes of the hopper are the same, and the figures to use on the square are found to be identical.

The angles shown will give the bevels at which to cut the roof boards to fit on the hips, also the bevels to cut the planchers and the bevels to miter the purlins. All of these bevels are similar.

48. The cut for the roof board on its face, or the cut to make it fit with the center line of the hip, is called the *face bevel*. The figures to use on the square for the boards on the end *BCGF* are those shown in Fig. 27 (*b*); namely, 18½ inches on the body and 9½ inches on the tongue, the cut to be along the tongue. For the jack-rafter, the body of the square will give the side cut. To miter the roof boards, take 22½ inches on the body of the square and 9½ inches on the tongue of the square, and cut along the tongue. The foregoing figures applied in the same way will also give the cut for purlins and planchers. The butt bevel is seldom used in roof framing, but in some cases it can be used instead of the miter bevel. The figures to use for the butt cut are 15½ inches on the body of the square and 9½ inches on the tongue of the square, cutting along the tongue.

49. The face bevel is the one most frequently used in roof framing; therefore, a method will be given for applying this bevel in fitting roof boards to hips on roofs of unequal pitch. By referring to Fig. 27, it will be noticed that *EK*, in (*a*), is equal to *E'M*, in (*b*), and that *L'E'* is equal to the length of rafter in the end of the roof. In other words, *EK* is the run of the right side of the roof, and *L'E'* is the length of rafter in the left side of the roof. Again, *LE*, in (*a*), is equal to *E'M'*, in (*c*), and *E'K'* is equal to the length of the rafters in the narrow roof; or, *LE* is equal to the run of the rafters in the left side of the roof, and *E'K'* is equal to the length of rafter in the right side of the roof. For the face cut of roof boards to fit over the hip in the right side of the roof, take the length of the common rafter ($L'E' = 18\frac{1}{8}$ inches) in the left side of the roof on the body of the square and the run of the common rafter ($EK = 9\frac{1}{2}$ inches) in the right side of the roof on the tongue of the square and cut along the tongue. For the face cut on the left side of the roof, to fit over the hip, take the length of the right common rafter ($E'K' = 15$ inches) on the body of the square and the run of the left common rafter ($LE = 14$ inches) on the tongue of the square, and cut along the tongue. For the face cut of jack-rafters, use the same figures on the square, but cut along the body.

50. Valley Roof of Unequal Pitch. In Fig. 28 is shown the plan of a valley roof of unequal pitch. The run of one side of the roof is 16 feet and that of the other is 7 feet, while the rise of each side is 16 feet. The following method may be employed to find the figures on the square to be used to obtain the required cuts and lengths of the common rafter. For the run and the rise, each equal to 16 feet, reduce the 16 feet to inches, which will give 192 inches run and 192 inches rise. To reduce these figures to the limit of the square, divide each by the same figure. In this case, divide by 16; thus, $192 \div 16 = 12$, which is used for both the run and the rise. Then, with 12 inches on the tongue of the square and 12 inches on the body of the square, the foot-cut and the ridge cut are obtained; and by stepping along the rafter timber sixteen times with the square, the length of the rafter will be determined.

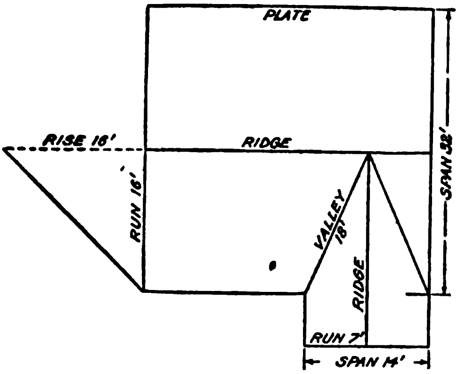


FIG. 28

To obtain the figures on the square for the rafters having a 7-foot run and a 16-foot rise, reduce the 7 feet to inches; thus, 7 × 12 = 84 inches. The rise has already been found to be 192 inches, and to reduce these figures to the limit of the square divide by 12, which will give 7 inches for the run and 16 inches for the rise. Take 7 inches on the tongue of the square, and 16 inches on the body of the square; the tongue will give the foot-cut and the body will give the plumb-cut. To obtain the length of the rafter, step along the rafter timber twelve times with the square, because 12 was the divisor.

By similar operations, the cuts and lengths of the valley rafters can be obtained. The rise of the valley rafters is known to be 16 feet, and the run can be determined either by scaling from the plate to the ridge along the plan line or by measuring the diagonal from 16 inches on the body of the square to 7 inches on the tongue of the square. The run of the valleys is a fraction over 18 feet; then, by taking 18 inches on the tongue and 16 inches on the body, the tongue will give the foot-cut and the body will give the plumb-cut. For the length, step along the valley timber twelve times with the square.

51. Hip and Valley Rafters for Roofs of Unequal Pitch.—Fig. 29 shows a method of finding the figures on a square to lay out hips and valleys for roofs of unequal pitch. Let *A B* represent the run of a common rafter, *B C* the rise, and *C A* the pitch. The body of square *No. 1* indicates a 12-inch run, and the tongue a 7-inch rise, which means that the rafter rises 7 inches per foot of run. Let *B D* represent the run of the rafter on the other side, *B E* the rise, and *D E*, the pitch. It will be noticed that the pitch of the rafter *A C* will not be the same as that of rafter *D E*, the latter being much steeper than the rafter *A C*. This is due to the fact that both rafters have the same total rise, but have different runs.

The seat angle of the hip, which is determined by the two pitches, will stand at an angle of 30° with the plates, as shown by the line *BF*. The figures to use on the square for the foot- and plumb-cuts of the hip while in this position are shown on square *No. 2* to be $13\frac{7}{8}$ inches on the body, for the run, and 7 inches on the tongue, for the rise. The length

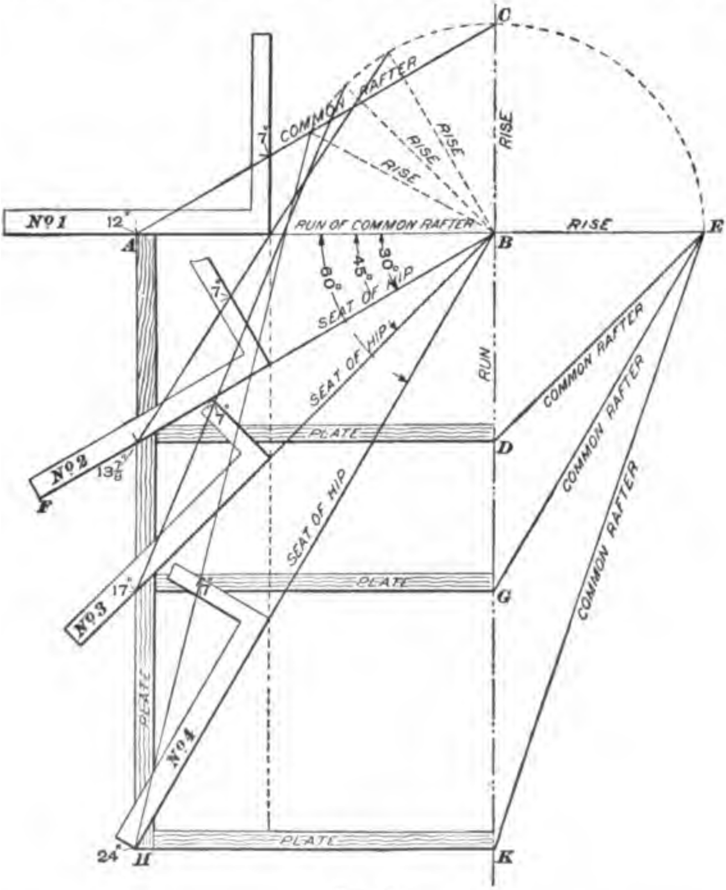


FIG. 29

can be determined by stepping along the hip timber the same number of times as for the common rafter.

52. In Fig. 29 is also shown the seat of a hip standing at an angle of 45° with the plates, and a common rafter *GE* that has the same pitch as the common rafter *A C*. As the two common rafters have equal pitches, they make an equal-pitch roof; consequently, the figures on the square to use for the foot- and the plumb-cuts of the hip rafters are *17* and *7*.

The line *B H* shows the seat of a hip at an angle of 60° with the plate; on the right is the common rafter *E K*, and

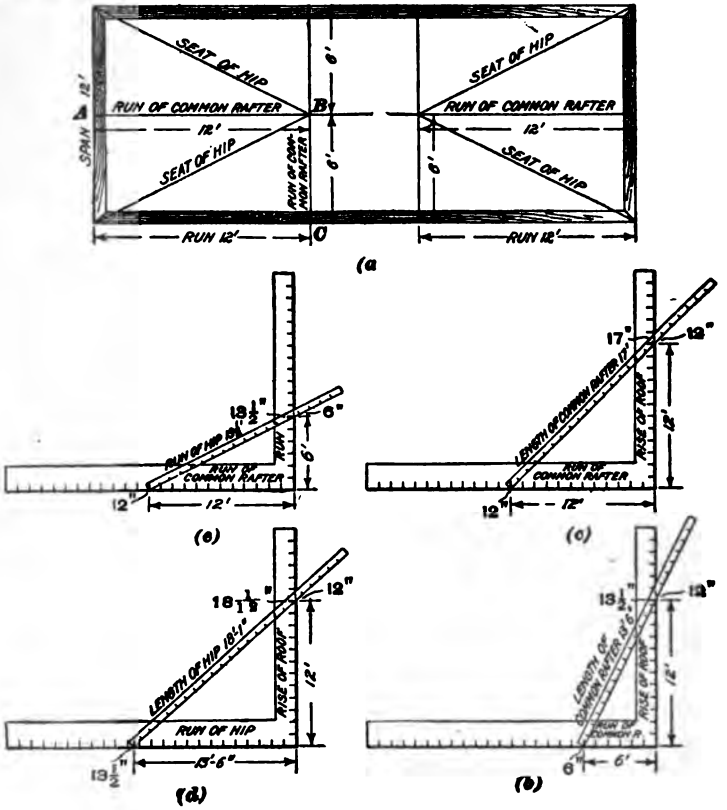


FIG. 80

on the left, the common rafter *A C* corresponding to this hip. On square *No. 4* are the figures to use for the foot- and the plumb-cuts of the hip rafter. The figures on the body remain constant for hips placed at these angles, but the figures on the tongue change as the rise of the common rafter changes.

53. Hip Roof With Unequal Pitches.—The hip roof shown in Fig. 30 (*a*) rises 12 feet, while the sides have a much steeper pitch than the ends. The variation in the seat angle of hips and valleys causes many difficulties in framing roofs of this kind. In roofs of equal pitch, the seat angle of the hip or valley is always known, while in unequal-pitch roofs there is no standard seat angle, and consequently, the figures on the square that will have to be used to obtain the cuts and lengths of hips and valleys must be found in each special case, according to conditions arising from differences involved in the pitches. Also, in roofs of unequal pitch, a great many complex problems affecting the layout of jack-rafters, roof boards, planchers, and every other timber that enters into the construction, are likely to arise.

54. In the plan shown in Fig. 30 (*a*), the rafters on the side have a run of 6 feet, while those on the end have a run of 12 feet. Both rafters, however, have the same rise. To lay out the rafter *CB*, use *12* on the tongue of the square for the run and *24* on the body of the square for the rise, because the rafter rises 12 feet in 6 feet, which is the same as a rise of 24 inches in 12 inches. For the length of the rafter, step with the square six times, using the figures *12* and *24*; or, to save time in stepping, take the bridge measure of *12* and *24* and multiply it by 6. Another method is to take the bridge measure of *6* and *12* and call the inches feet, as shown in Fig. 30 (*b*).

To lay out the end rafter *AB*, use *12* on the body of the square and *12* on the tongue of the square for the cuts. For the length of the rafter, step twelve times along the rafter timber, or, as before described, take the bridge measure as shown in (*c*). The figures made use of on the square for both of these rafters will give, for each slope, a rafter that will have a total rise of 12 feet. For the rafter *CB*, 12 inches on the tongue for the run, and 24 inches on the body for the rise should be used, while the length is found by stepping off six times; now, multiplying 24 inches by 6 will give 144 inches, or 12 feet, for the rise. In laying out rafter *AB*, 12 inches on the body of the square and 12 inches on the tongue of the square should be used, and the length can be found by stepping twelve times; consequently, the rise is 12 × 12 = 144 inches, or 12 feet.

55. In laying out a hip, the first thing to consider is its length, which may easily be found by means of a 2-foot rule and a steel square. Place the rule across the square, from *12* on the body to *6* on the tongue, as shown in Fig. 30 (*e*); the rule will indicate a distance of 13 feet 6 inches, which is the correct length of the run of the hip. Having determined the run, take the bridge measure of this run and the total rise on the square, or 13½ inches on the body and 12 inches on the tongue, as shown in (*d*). The length, therefore, will be 18 feet 1 inch.

56. By referring to Fig. 31, the operation of framing rafters for unequal-pitch roofs may be further explained.

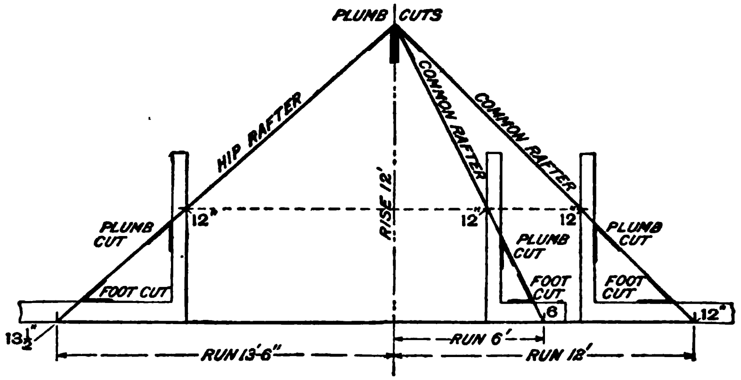


Fig. 31

This figure illustrates the principles underlying the handling of the square in this connection. On the right side is shown the pitch of the rafter over the ends of the building. These rafters have a rise of 12 inches per foot of run. The square as applied shows the figures *12* on the body and *12* on the tongue, which are the ones to be used for the foot- and plumb-cuts. On the same side is also shown the rafter for the narrow side of the roof, and the figures *6* and *12* indicate the position of the square when marking the rafter for the foot- and plumb-cuts, *6* and *12* being in the same proportion as 12 and 24. On the left side of the illustration is shown the hip rafter, and the figures on the square used for the foot- and plumb-cuts.

57. Another method of ascertaining the run of a hip, relative to a foot-run of a common rafter, is shown in Fig. 32, in which the plan lines of two of the hips are represented by *A C* and *B C*, and the plan line of a common rafter by *D C*. The method consists in measuring 12 inches from *D* to *E* on the rafter line *D C*, as shown, and drawing the line *E F* at right angles to *D C*, cutting the plan line of hip *B C* at *F*. The portion *B F* of the hip line indicates the foot-run of the hip relative to a foot-run of the common rafter.

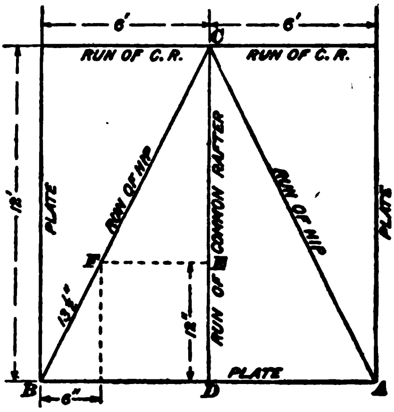


Fig. 32

58. The bevels for the jack-rafters and roof boards are shown in Fig. 33, which is a plan of the roof shown in Fig. 30 (*a*). In Fig. 33, *CDEF* represents the plates. To show how the figures to cut the jack-rafters and roof boards are obtained, it will be necessary to unfold the roof, that is, to show the roof surfaces laid in a horizontal position. In order to do this, imagine that the roof is hinged at the plates, so that the four surfaces can be opened like the lid of a box, the joints of the lid being the four hip rafters and the ridge of the roof. Now, if this lid is laid in a horizontal position, the plan lines of the hips will be the true lengths; but, as the lid is inclined from the horizontal, it is evident that the true lengths of the joints, with the exception of the ridge, will be longer than the plan lines show. The lengths of the ridge line will be

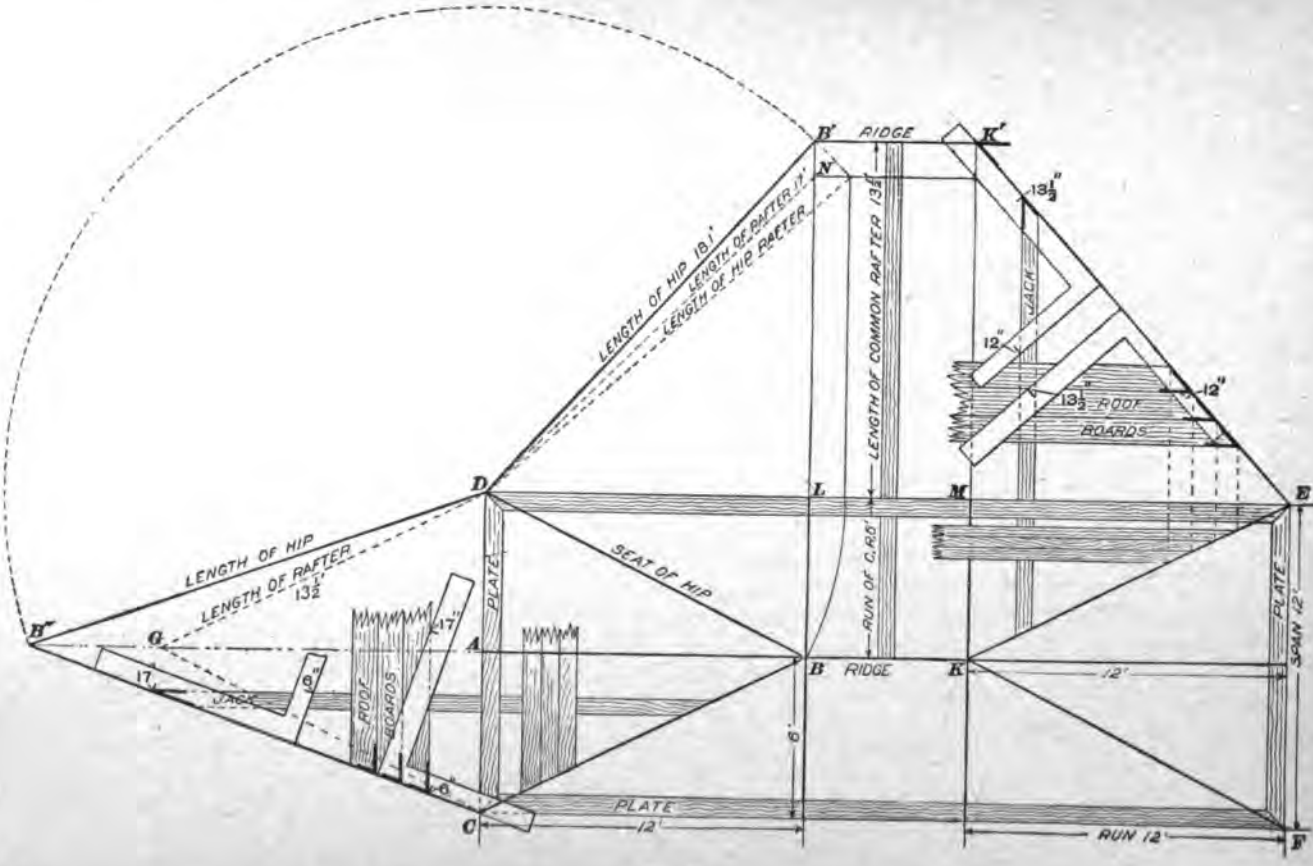

B′
RIDGE
K′
N
13½″
LENGTH OF HIP 18.1′
LENGTH OF RAFTER 17′
LENGTH OF HIP RAFTER
LENGTH OF COMMON RAFTER 13½′
JACK
12″
13½″
ROOF
BOARDS
12″
D
L
M
E
RUN OF C.R.6′
SEAT OF HIP
LENGTH OF HIP
LENGTH OF RAFTER
13½′
PLATE
B″
G
A
17″
6″
17
JACK
ROOF
BOARDS
6
B
RIDGE
K
12′
SPAN 12′
PLATE
6′
PLATE
C
12′
RUN 12′
F

FIG. 33

the same, because it is a horizontal line and is also parallel with the hinged line, or line of plates.

59. First, consider the long, narrow section of roof. Let *DE* be the line along which the roof is hinged, and *DB*, *BK*, and *KE* the joints; then, by opening the lid and bringing it into a horizontal position, the points *B* and *K* will rest at *B′* and *K′*, and in order to lay out this surface, all that is necessary is to find the points *B′* and *K′*. Now, *BL* is the plan of a line on the lid; in this case, it is the plan of the common rafter. The true length of this line is shown at *DG*. By making *LB′* and *MK′* each equal to *GD*, and connecting *B′D* and *K′E*, the true size and shape of *DBKE* will be shown at *DB′K′E*. Any lines or angles laid on this shape will be the true lengths and angles; consequently, the lines *DB′* and *K′E* equal the true lengths of the hips.

The bevels shown for the roof boards and the jack-rafters are the true bevels, and the figures to use on the square are taken from the triangle *EMK′*. *ME* is the run of the common rafter on the end, and *MK′* is the length of the common rafter on the side. Then, by taking *ME* on the tongue of the square and *MK′* on the body of the square, and cutting along the body, the cheek cut of the jack-rafters will be given. As the roof boards are placed at right angles to the jack-rafters, the figures on the square used to obtain the cuts of the jack-rafters will give the face cut of roof boards, but instead of the body giving the cut, it will be necessary to cut along the tongue. The angle, or bevel, shown at *K′* is the one to use for the side cut of a hip rafter when it is backed. This bevel is the same as for the roof boards, and the one to use for planchers.

60. The end lid is developed in exactly the same manner as the side. Lay off the line *AB″* equal to the length of the common rafter *DN*; connect *B″D* and *B″C*; and these last two lines will be equal in length to the hips. When the plan *DBC* is opened and turned to a horizontal position, the point *B* will revolve to *B″*. The figures on the square to use for the side cuts of jack-rafters and roof boards will be obtained from the distance *A C*, which is equal to the run of the common rafters on the side of the roof, and *A B''*, which is equal to the length of the common rafters on the end of the roof. From the foregoing description, rules may be formulated for finding the figures on the square to use when laying out jack-rafters and roof boards for unequal-pitch roofs, provided the ridges are of the same height.

Rule I.—*To find the cheek cuts of jack-rafters in the side of the roof, take the run of the common rafter in the end of the roof on the tongue of the square and the length of the common rafter in the side of the roof on the body of the square, and cut along the body.*

Rule II.—*To find the cheek cuts of jack-rafters in the end of the roof, take the run of the common rafter in the side of the roof on the tongue of the square and the length of the common rafter in the end of the roof on the body of the square, and cut along the body.*

Rule III.—*To find the cut for roof boards, use the same figures on the square as for laying out the cheek cut for jack-rafters, but cut along the tongue instead of the body.*

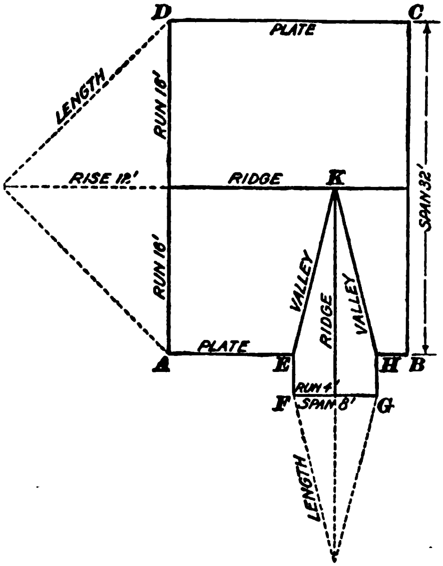


FIG. 34

61. Valleys on Roofs of Unequal Pitch.—Although the length and cut of valley rafters are very similar to those of hip rafters, it may be well to show an example of a valley roof of unequal pitch. Fig. 34 illustrates the plan of such a roof. In this illustration, *A B C D* represents the plates of the wide roof, and *EF*, *FG*, and *GH* the plates of the narrow roof. The run of the rafter on *A D* is 16 feet, and on *FG*, 4 feet. Each roof has the same rise and their ridges intersect at *K*. The seats of valleys are shown to reach from *E* to *K* and from *H* to *K*. The methods of determining the lengths of the rafters have already been explained. The figures on the square to be used in obtaining the foot- and the plumb-cut are *16½* and *16*, while the length may be found by stepping twelve times along the valley timber. These figures are derived by reducing the run and the rise to inches and dividing by 12.

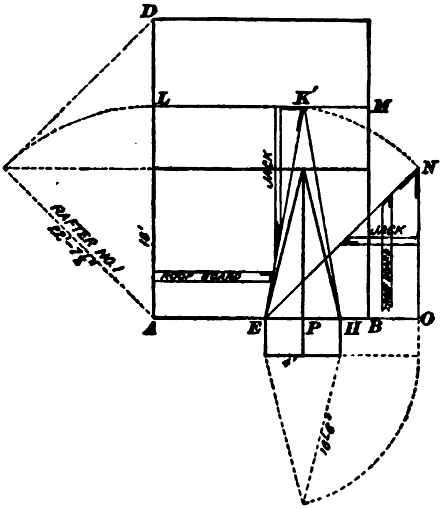


FIG. 35

62. Fig. 35 shows the same plan lines as those given in Fig. 34. By revolving rafter *No. 1* to *L* and drawing the line *L M* parallel with the ridge, the figure *A L M B* will show the true size and shape of one side of the main roof, in which *A L* and *M B* are the true lengths of the common rafters. The point *K'* is where the ridge of the small roof intersects the ridge of the main roof. Connect *K'* and *E*, and *K'* and *H*; then, these two lines will represent the true length of the valley rafters, and the bevel shown at *K'* will be the cheek cut for the valley rafter, provided it is backed. Revolve the valley *E K'* to *N*, connect *N* and *E*, and make *E O* equal to the length of the gable rafter in the small roof; also connect *N* and *O*. Then *N O* will equal the run of the common rafters in the main roof, and *E O*, the length of the common rafters in the small roof. The triangle *E O N* represents the true size and shape of one side of the small roof, when it is laid in a horizontal position.

The bevel shown in *N* is the true bevel for the cheek cut of the valley rafter, to fit against the ridge of the small roof, provided the valley is backed. The true cheek and face cuts of jack-rafters and roof boards are shown, and the figures to use on the square are found in the same manner as shown in Fig. 33. For the side cuts of jack-rafters on the small roof, take the run of the common rafters on the large roof, which is equal to *NO* on the tongue of the square and the length of the common rafter on the small roof, which is equal to *EO*, on the body of the square, and cut along the body. For the side cut of jack-rafters on the large roof, take the run of the common rafter in the small roof, which is equal to *EP* on the tongue, and the length of the common rafter in the large roof, which is equal to *PK'* on the body, and cut along the body. For roof boards, cut along the tongue of the square. For the bevel *N* to fit the valley on the small ridge, the same figures

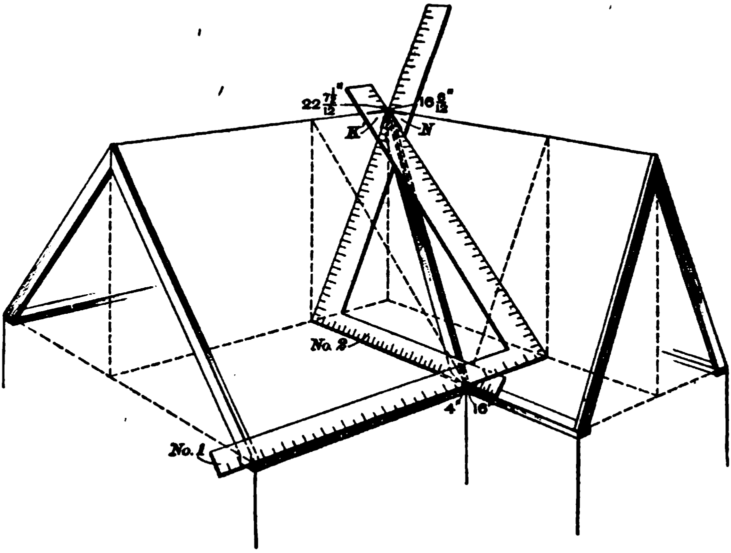


Fig. 36

are used as for roof boards, and the bevel at K' is set at the angle used for cutting the roof boards.

63. Fig. 36 shows a perspective view of an unequal-pitch roof with two squares applied to the valley in such a position that they will probably illustrate more clearly why certain figures on the square are used. It will be noticed that square *No. 1* has the run of the small roof and the length of the rafter in the large roof, while square *No. 2* has the run of the large roof and length of the rafter in the small roof. It should be remembered, however, that these bevels for the side cut of valleys hold true only when the valley is backed.

64. Laying Out Unbacked Hip or Valley Rafters. In roof framing, valleys and hips are seldom backed, the practice being to use the timber in the rough, as received from the yard. When hips and valleys are not backed, the figures to use on the square to obtain the side cut are different than when backed. This difference is due to the fact that the top edges of the timber are not in the same plane with the roofs on either side. The backing of a hip or a valley brings both top edges in the same plane with the intersecting roofs. In order to find the figures for getting the side cut when timber is not backed, it is necessary to make a drawing, as no rule can be formulated that will hold true for the various combinations of intersecting roofs.

Owing to the fact that the seat of the hip or the valley in equal-pitch roofs stands at an angle of 45°, the expression for side cut remains constant for every pitch. This expression may be stated in the form of a rule, thus:

Rule.—*To find the side cut for hip or valley rafters on equal-pitch roofs, take the run of the hip or the valley on the body of the square and the length of the hip or the valley on the tongue of the square, and cut along the tongue.*

65. In Fig. 37 is shown a method of finding the figures to use on a square in making the side cut of hip or valley rafters when the timbers are not backed. The roof shown in this figure is the same as that shown in Figs. 34 and 35, and the development of the roof surface and the point K is the same as in Fig. 35. The line EK', Fig. 37, is the true length of the valley rafter. To find the cheek bevel, or side cut, of a valley rafter to fit against the main ridge, produce the seat of valley EK to EK'', making the latter equal in length to EK'. Produce the line of the main ridge to S. From the point E, where the valley intersects the plates, draw ES at right angles to EK, and connect S and K''; then, $SK''E$ will be the correct angle to use. The figure to use on the square will be the distance ES on the body, and the distance EK'', which is equal to the length of the valley, on the

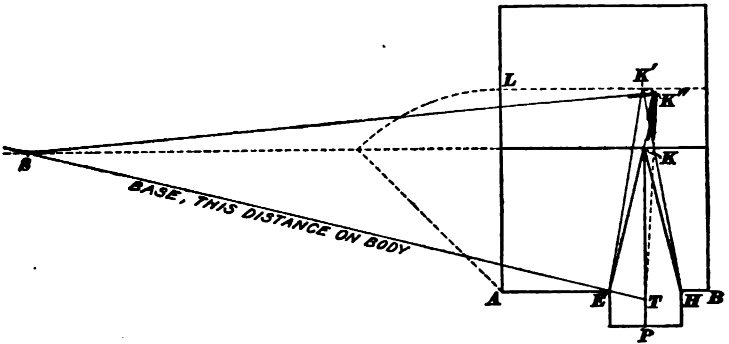


FIG. 37

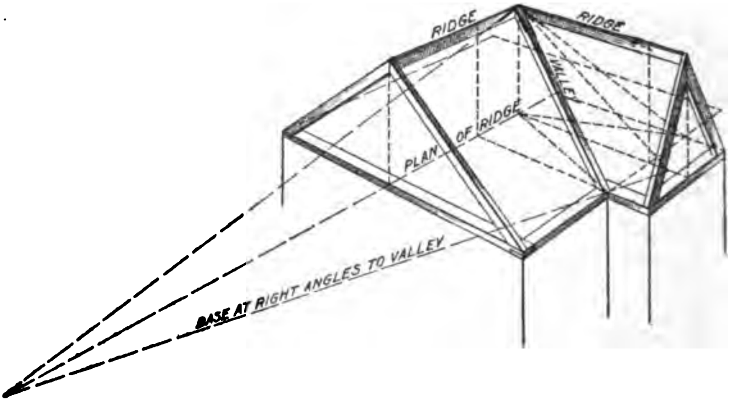


FIG. 38

tongue, the tongue giving the cut. It will be observed that the line marked *base* will change as the seat of the valley changes. When the seat of the valley makes an angle of 45° with the plates, then the base will be equal to the seat of the valley, or will have the same length as the run.

To find the bevel of the valley, after the fit against the dormer ridge, draw the line *E T* at right angles to *E K* and connect *T* and *K''*; then, the angle *E K'' T* will be the correct bevel for the cut of the valley rafter. The figures to use on the square will be the distance *E T* on the body and *E K''*, which is equal in length to the valley, on the tongue, cutting along the tongue.

A perspective view of the roof shown in Fig. 37, containing the construction lines, is illustrated in Fig. 38. As shown in this view, the back of the valley timber, as placed in position at the intersection of the two roofs, is square, while in Fig. 36 the valley is run in line with the plates, as they would do when backed.

66. Ridges of Different Heights.—When the ridges of a roof of unequal pitch are not the same height above the plates, the expressions on a square to obtain the cuts are somewhat changed. Fig. 39 shows a roof in which the dormer ridge does not extend so high above the plates as the main ridge. In the illustration, *A B C D* represents the plates of the main roof; *E F G H*, the plates of the dormer; *E J*, the seat of the short valley; and *H K*, the seat of the long valley.

To find where the valleys intersect in the plan of the main roof, produce the line of the main ridge to *M*. Make *N M* equal to the rise of the main roof, and *N O* equal to the rise of the dormer roof. Connect *A* and *M*; then, *A M* will represent the length and pitch of the main roof. From *O*, lay off a right angle to *M N*, and this line will intersect the pitch line at *P*; then, *O P* will represent the plan distance from the ridge to where the valleys intersect, and *M P*, the true distance along the roof from the ridge where the valleys intersect. From *P*, draw the line *P J* parallel with the ridge line,

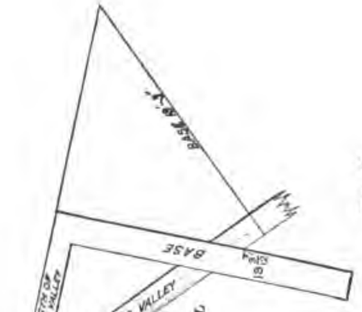


FIG. 40

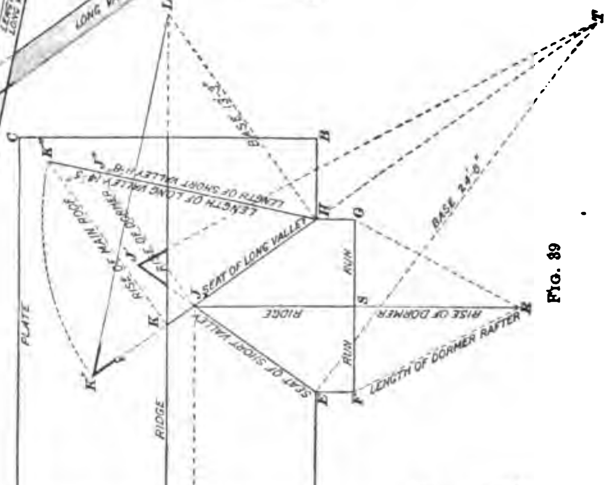


FIG. 39

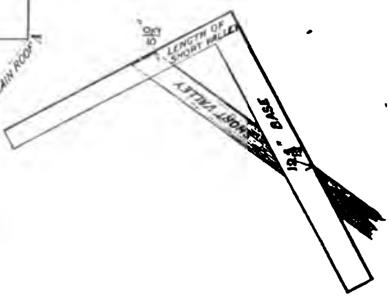


FIG. 41

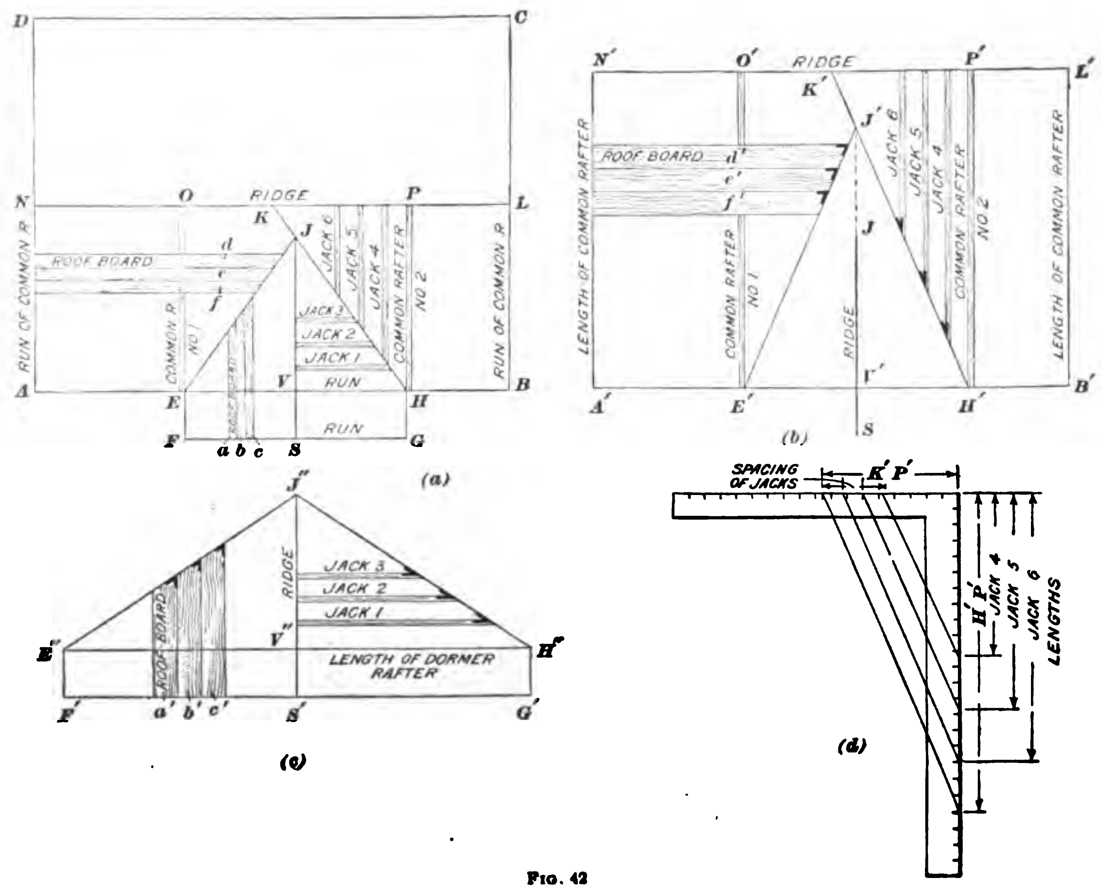
and where this line intersects the ridge line of the dormer will be the point of intersection of the valleys in the plan.

67. The seat of the long valley can be determined by drawing a line from *H*, Fig. 39, through *J*, to the ridge at *K*. The seat of the short valley will be the line *EJ*. The length of the dormer gable will be found by laying off the line *SR* equal to the rise of the dormer *ON* and connecting *F* and *R*, and *G* and *R*; then, *FRG* will be an elevation of the dormer gable.

To find the lengths of the long and short valleys, erect perpendiculars to *HK* at *J* and *K*, making KK'' equal to the rise of the main roof, and JJ'' equal to the rise of the dormer roof. Connect K'' and *H*—this line will also pass through J''—then HK'' will be the length of the long valley, and HJ'' the length of the short valley. For the foot- and plumb-cuts, take *KH* on the body of the square, and KK'' on the tongue of the square; the body will give the foot-cut and the tongue will give the plumb-cut for both valleys.

To find the bevel of the long valley to fit against the main ridge, erect a perpendicular to *HK* at *H*; this line will intersect the main ridge, or ridge produced, at *L*. Produce the seat of the valley to K', making HK' equal in length to the long valley. Connect LK'; then the angle $LK'H$ will be the desired bevel. The figures to use on the square will be found by taking the distances *HL* on the body and HK' on the tongue, and cutting along the tongue. Fig. 40 shows the application of the square.

68. To find the side cut to fit the short valley against the long valley, make EJ', Fig. 39, equal in length to the short valley, and produce the long valley to *T*. Erect at *E* a perpendicular to the seat of the short valley; this line will intersect the produced line of the long valley at *T*, and the angle $EJ'T$ will be the desired bevel. The figures to use on the square will be the base *ET* on the body and the length of the short valley EJ' on the tongue, cutting along the tongue. The method of finding the bevel to fit the short valley against the ridge has already been explained. The


D
C
N
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RIDGE
P
L
K
J
d
e
f
ROOF BOARD
RUN OF COMMON R
COMMON R
NO 1
JACK 6
JACK 5
JACK 4
COMMON RAFTER
NO 2
JACK 3
JACK 2
JACK 1
RUN
A
E
V
H
B
F
a b c
S
G
(a)
N'
O'
RIDGE
P'
L'
K'
J'
ROOF BOARD
d'
e'
f'
LENGTH OF COMMON RAFTER
COMMON RAFTER
NO 1
J
RIDGE
V'
JACK 6
JACK 5
JACK 4
COMMON RAFTER
NO 2
A'
E'
H'
B'
S
(b)
J''
RIDGE
JACK 3
JACK 2
JACK 1
V''
E''
H''
ROOF BOARD
LENGTH OF DORMER RAFTER
F'
a'
b'
c'
S'
G'
(c)
SPACING OF JACKS
K'P'
H'P'
JACK 4
JACK 5
JACK 6
LENGTHS
(d)

FIG. 42

application of the square to the short valley is shown in Fig. 41.

As the length of the base is beyond the limits of the square, it is necessary to reduce the distances. In order to do this, divide both the length of the base, which is 24 feet 8 inches, and the length of the short valley, which is 11 feet 8 inches, by 2, thus giving $12\frac{4}{12}$ inches for the figures on the body, and $5\frac{10}{12}$ inches for those on the tongue. These figures will give the same angle as the figures 24 feet 8 inches and 11 feet 8 inches.

69. The expression for the side cuts of jack-rafters and for the face cuts of roof boards changes when the ridges are not of the same height; this is due to the run of the main roof not being the same as the length of the dormer ridge from the plate to the intersection of the roofs. Fig. 42 (*a*) represents the same plan as that shown in Fig. 39. On one side of the dormer, the jack-rafters are shown in place, and on the other side, the roof boards. It will be noticed that the dormer ridge VJ is shorter than the run of the common rafter in the main roof; consequently, the distance along the ridge KP is longer than the run of the dormer rafter. If the ridges were of the same height, the ridge JV would be equal to the common rafter PH, and the distance KP would be equal to the run VH of the dormer rafters. Owing to these changed conditions in the length of runs, under different conditions, it will be necessary to find an expression on the square that will cover every case.

70. Fig. 42 (*b*) shows a development of one side of the main roof; in other words, it shows one side laid down flat, or in a horizontal position. The lengths of the common rafters are taken from Fig. 39.

To make the development shown in Fig. 42 (*b*), draw $A'B'$ equal in length to AB, in (*a*); lay off $A'N'$ and $B'L'$ at right angles to $A'B'$ and equal in length to the common rafter in the main roof; and draw $N'L'$ equal in length to the ridge NL, in (*a*). On the line $A'B'$, in (*b*), lay off $A'E'$, $E'V'$, and $V'H'$ equal to AE, EV, and VH, in (*a*).

On the line $N'L'$, lay off $N'K'$ equal to NK, in (*a*); connect K' and H', and $K'H'$ will be the length of the long valley. From V' erect a perpendicular to $A'B'$, intersecting $K'H'$ at J'; connect J' and E', and $J'E'$ will be the length of the short valley. As will be noticed, all lines in the plan that are parallel with the plates remain the same length in the development, only those lines which are inclined or make an angle with the plate being changed.

71. To develop the dormer, Fig. 42 (*c*), lay off the ridge line $V''J''$ equal in length to VJ, in (*a*). At right angles to this line, lay of $V''H''$ and $V''E''$ equal in length to the dormer rafter. Connect H'' and J'', and E'' and J''; then $E''J''$ will be equal in length to the short valley, and $H''J''$ will be equal to $H'J'$, in (*b*).

Any lines laid down on either of these developments will be the true lengths of the lines, and the angles made will be the true angles. First consider the jack-rafters and roof boards in Fig. 42 (*b*). As all the lines in this illustration show the true lengths, it is simply necessary to scale the lengths of the jack-rafters to obtain their true length; or, the lengths may be formed by setting a bevel instrument on a square so that the blade will cross at a point equal to the distance $K'P'$ on the tongue and $H'P'$ on the body. The lengths of the different jack-rafters can be found by sliding the bevel along the tongue of the square the number of inches that the rafters are spaced feet on centers, reading the length of rafters on the body of square as shown in (*d*).

The lengths may also be determined by the proportion $K'P' : H'P'$ = distance between centers of jack-rafters : difference in lengths of jack-rafters.

Assuming that $K'P'$ is equal to 8 feet 6 inches, and $H'P'$ to 20 inches, and that the spacing of jack-rafters is 2 feet, then the difference in lengths of jack-rafters will be

$$8.5 \text{ feet} : 20 \text{ feet} = 2 \text{ feet} : 4.7 \text{ feet};$$

or,

$$\frac{20 \times 2}{8.5} = 4.7 \text{ feet} = 4 \text{ feet } 8.4 \text{ inches}$$

For the side cuts of jack-rafters, take the distance *K' P'* on the tongue of the square and *P' H'* on the body, and cut along the body. For the roof boards, use the same figures on the square, but cut along the tongue. These figures also apply to the jack-rafters and roof boards on both sides of the dormer in the main roof.

For any roof of this description, scale the distance *K' P'*, Fig. 42 (*b*), along the ridge; then, take this distance on the tongue of the square and the length of the common rafter in main roof on the body, and cut along the body.

72. For the lengths of jack-rafters in the dormer, use any of the methods just described. The proportion will be *V'' J''* : *V'' H''* = distance between centers of jack-rafters : difference in lengths of jack-rafters. For the side cuts of jack-rafters, take the distance *J'' V''* on the tongue of the square and *V'' H''* on the body of the square, and cut along the body. For the roof boards, use the same figures, but cut along the tongue.

To obtain the cuts in any dormer of this description, take the length of the ridge from the plates to the intersection on the tongue of the square and the length of the common rafter in the dormer on the body of the square, and cut along the body. The jack-rafters and roof boards have the same relative positions in the developed roofs as they have in the plan. The foregoing expressions for obtaining the side cuts also hold true when the ridges are of the same height.

73. Laying Out Side Cuts for Hip Rafters.—The side cut of a hip or a valley rafter is usually more difficult to obtain than any other cut, which is especially true when the timbers are not backed. In the preceding articles, the methods of finding the side cut of hip and valley rafters have been explained, but in the examples given, the plates of the building were at right angles. In Fig. 43 is shown a plan of the roof of unequal pitch, in which one end of the roof is not at right angles and the hips on the other end are not true hips, for the reason that the plan lines of the hips are not at an angle of 45° with the plates. The two sides have the same pitch, but the two ends pitch differently, and neither end has the same pitch as the sides; consequently, the roof has three pitches.

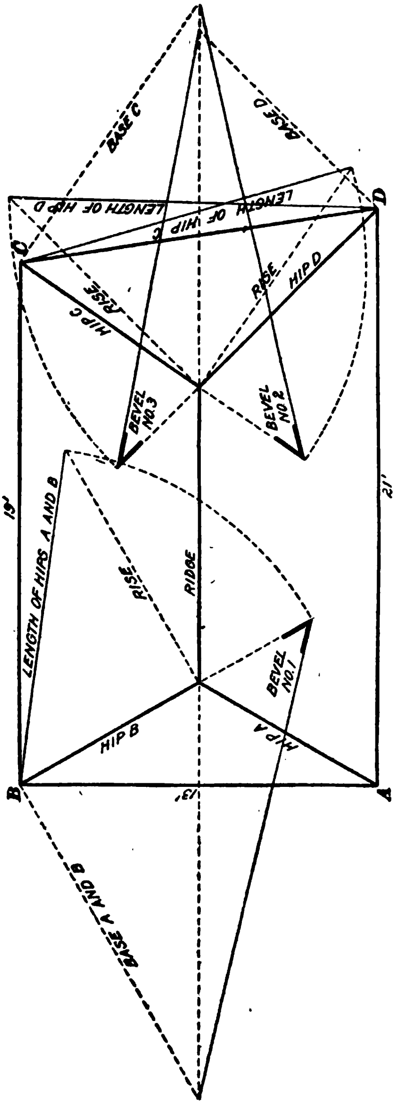

Fig. 43

The angle of bevel for the side cut of the hips at the left end, or hips *A* and *B*, is shown at bevel *No. 1*. To find this angle, erect through *B*, a right angle to the run of the hip, and project this line to the main ridge produced. Extend the seat of the hip so that it equals the length of the hip; connect this point with the point on the ridge, and the bevel for both hips is at the angle marked bevel *No. 1*. For the right-hand end, the construction is the same as for the left end.

To find the bevel for hip *C*, extend the hip *C* a distance equal to the length of the hip, then through *C* draw a line at right angles to the run of the hip, intersecting the main ridge produced; connect these two points, and bevel *No. 2* will be the correct angle to fit hip *C* against the ridge.

For the side cut of hip *D*, draw through point *D* a line at right angles to the run of hip *D*. Extend hip *D* so that it is equal to the length of hip *D*; connect these points, and bevel *No. 3* will be the correct angle to use.

74. The figures to use on the square are found by scaling the base and taking this distance on the body and the length of the hip on the tongue, cutting along the tongue. If the ends of the plates are to butt, the figures to use to get the cut will be the difference in length between the two sides on the tongue of the square and the span of the building on the body, cutting along the body. Thus, assume that the short side of the building is 19 feet, and that the long side is 21 feet; then, the difference will be 2 feet. Again, assume that the span of the building is 13 feet; then, 2 inches on the tongue of the square and 13 inches on the body, and cutting along the tongue, will give the angle.

75. The roof illustrated in Fig. 43 is shown developed and unfolded in Fig. 44. Assume that the sides and ends are hinged on the plates, and that it is desired to find the position that each part composing the lid will occupy when it is open and the parts are laid in a horizontal position.

To open part *A*, extend the run of the common rafters that are at right angles to the plates and equal in distance to the length of the common rafters. Connect these two points at the ends, which will give the ridge line; then, connect the points on the ridge with the corners of the plate and the end joints will be shown in their true length. These lines will correspond with the true lengths of the hip, and the part *A'* will be the true size and shape of the side *A*, and the true lines and the angles will be shown.

For part *B*, lay off the length of the common rafter at right angles to the plates, and draw the triangle *B'*. In this part, the jack-rafters are shown at right angles to the plates, which is the best way of framing them. If the jack-rafters are to be parallel with the side plates, the line length and angle will be shown by drawing lines on the part *B'* and making them parallel with the plates.

The method of developing part *C* is the same as that used for part *A C′*, showing the true size and shape.

For part *D*, lay off the length of the common rafter at *D*, making it at right angles to the plate; then, draw the triangle as shown at *D′*.

76. The true bevels and lengths of all the members of the roof having been shown, an expression for finding the figures on the square may readily be taken from the drawing. Thus, the side cut of jack-rafters in *A′*, Fig. 44, to fit against the hip in *B′* is run on body, length on tongue, and cut on tongue, the run and length giving the figures for each timber. It will be observed that all construction lines in the development are right-angle lines, and that these construction lines represent the true length of the common rafter in each part.

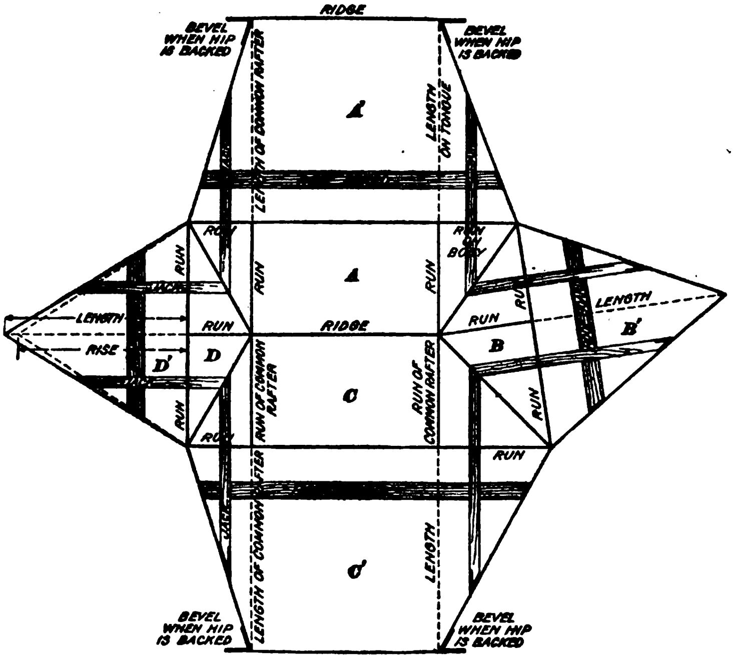

FIG. 44

To more clearly show the size and shape of this roof, take a piece of cardboard, mark the outside lines, and then cut out the figure, making a cut along the plate lines about half way through the board; then, fold the parts *A′*, *B′*, *C′*, and *D′* until the edges meet. In this way, the true pitches of the sides will be shown.

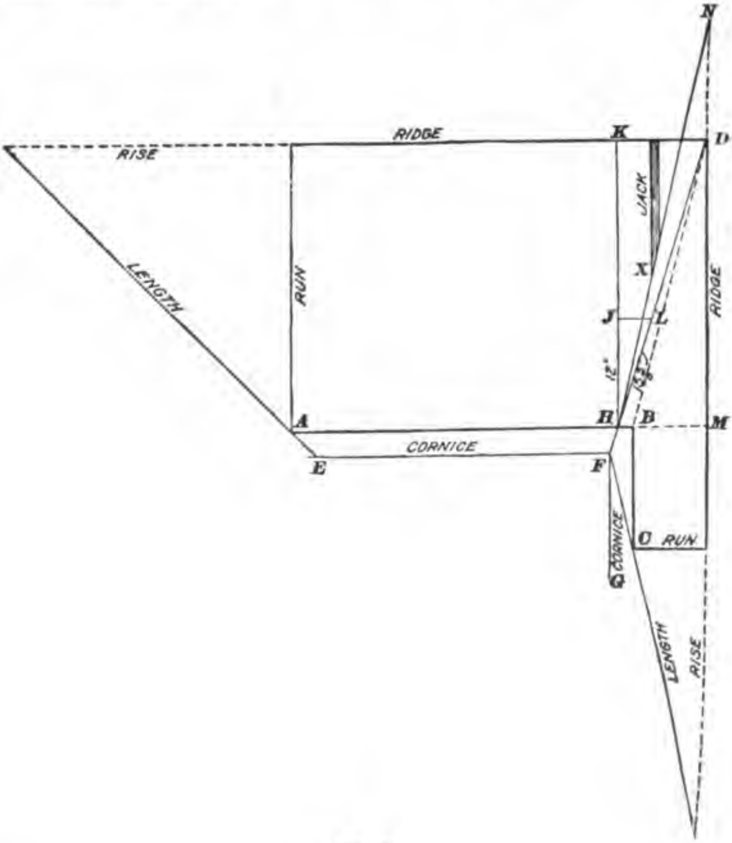

FIG. 45

77. Relation of Cornice Plate and Rafters.—Fig. 45 shows the plan lines for one-half of a roof having an unequal pitch, being similar to the roof shown in Fig. 34. The wide portion of the roof has a run of 16 feet and a rise of 16 feet, while the narrow portion has a run of 4 feet and a rise of 16 feet. The plates are shown at *AB* and *BC*. The seat of the valley, irrespective of the cornice, should extend from the intersection *B* of the plate to the intersection *D* of the two ridges, as shown by the dotted line *BD*, but as the cornice projects beyond the plates, as shown at *EF* and *FG*, the seat of the valley will have to be placed as shown, from *F* to *D*, intersecting the plate *AB* at *H*.

To lay out the valley when in this position, its relative run to the foot-run of the rafters must be found. Let the line *HJK* represent the plan line and *HJ* the foot-run of the rafter. From *J* draw a line to cut the seat of the valley at *L*; then, *LH* will represent the run of the valley relative to a foot-run of the rafter.

By continuing the plate *HB* to *M* and making *MN* equal to the length of the rafter, a line drawn from *N* to *H* will represent the length of the valley, and its position as here indicated will define the cheek bevel of the jack-rafters, as shown at *X*.

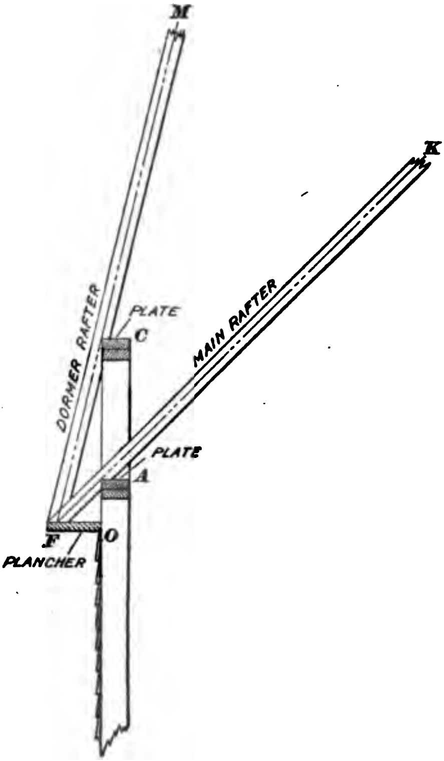

Fig. 46

To lay out the valley, take the length *HL*, which is the run of the valley relative to a foot-run of the rafter, on the body of the square and the rise of the roof to a foot-run, on the tongue of the square; the body will then give the foot-cut, and the tongue, the plumb-cut. By stepping along the valley timber sixteen times, the length is determined; to this length should be added the projecting portion from the plate at *H* to the cornice line at *F*.

78. Relative Heights of Intersecting Plates.—In Fig. 46 is shown a vertical section of the rafters and plates shown at *B C*, Fig. 45; in Fig. 46, however, plate *C* is placed much higher than plate *A*. To determine the relative heights of the two plates, let *F* represent the intersecting point of the cornice. From *F* draw the pitch of the wide side of the roof from *F* to *K*, as shown. Also, from *F* draw the pitch of the narrow side of the roof from *F* to *M*. Let *F O* equal the width of the cornice, and through *O* draw the face line of the building, *O A* representing the distance from the plancher to the upper face of the plate of the wide side of the roof, and *O C*, the distance to the upper face of the plate of the narrow side of the roof. The distance from *A* to *C* indicates the difference in heights between the two plates.

DETAILS OF ROOFS AND TOWERS

79. Bevels for Square Towers.—Fig. 47 illustrates a plan and elevation of a square tower, or pyramid. The purlin line is shown at *A B*, while at *B* is shown the face bevel for the purlin. To find the miter bevel *D*, draw the line *A E* at right angles to the slant of the tower; make *A D* equal to *A C*, and connect *D E*, which will give the correct angle for the miter. The figures to be used on the square to lay out bevel *D* will be the length of *A D* on the tongue and the length of *A E* on the body, the tongue giving the cut. For the bevel *B*, take the length of *B F* on the tongue and the length of *F A* on the body; the tongue will give the cut. The line *F A* is drawn at right angles to the pitch of the tower from point *A*.

To find the face bevels, draw from *H* the line *H L* at right angles to the side of the tower, and from *K*, the line *K M* at right angles to the other side. Draw *H L'* square to *H K*, and make it equal in length to *HL*. Connect *L'K*; then, *K* will be the bevel to apply to the upper face of the brace, and *G* will be the bevel for the side, or the plumb-bevel. These two bevels applied to the bottom end of the brace, as at *G* or *K*, will indicate how to mark the brace so as to fit the sides of the tower. The bevel at *H* is the side bevel for the top end of the brace, and is found as follows: From *K* and square to the line of brace *KH*, draw the line *KM'*, making it equal in length to *KM*. Connect *M'H*; then, the angle *KHM'* will be the correct bevel. The other bevel is shown at *J*.

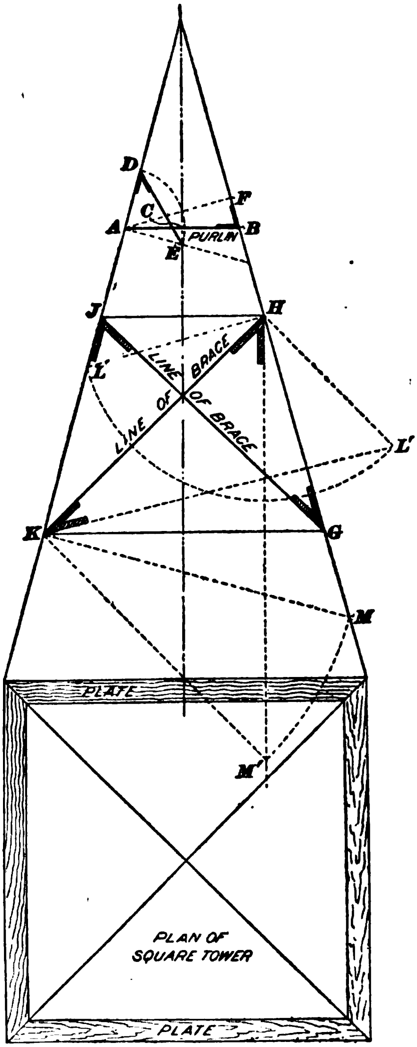

Fig. 47

80. Octagonal Roofs and Towers.—To find the figures on the square to lay out the hips of an **octagonal roof,** use the method shown in Fig. 48, which illustrates the plan of an octagonal roof. The common rafters in octagonal roofs and shed, or hip, roofs are alike. The same figures give the plumb- and foot-cuts, and the length is determined in the same manner on the square.

In Fig. 48, square *No. 1* indicates a pitch of 16 inches per foot of run for the common rafter. By producing the dotted line *d* from the body of square *No. 1* to intersect the plan line of the hip *A c*, square *No. 2* placed as shown will indicate the figures *13* on the tongue and *16* on the body, which are the proper points for the rise of the hip rafter. In other words, the common rafter rises 16 inches in every 12 inches of run, and the hip rafter rises 16 inches in every 13 inches of run. The 13 inches remains constant on the tongue no matter what the rise is on the body.

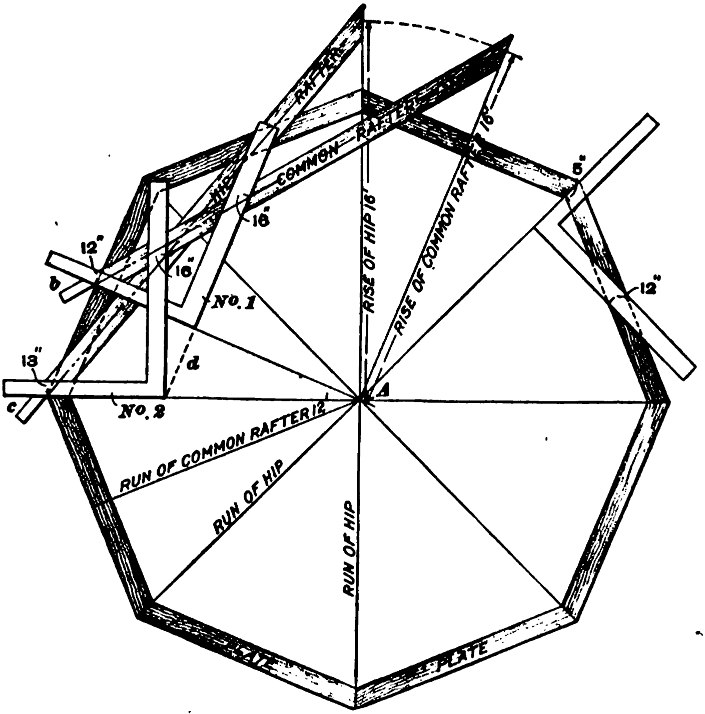

FIG. 48

If the total run of the common rafter is 5 feet, the length may be found by stepping along the rafter timber five times with the figures shown on square *No. 1*; that is, 12 inches on the tongue for the run and 16 inches on the body for the rise. The length of the hip rafter can be found by stepping along the rafter timber five times, the same as for the common rafter, but the figures on the square in this case will be 13 inches on the tongue for the run and 16 inches on the body for the rise. The foot-cut of the hip rafters will be 13 inches on the tongue and 16 inches on the body, the tongue giving the cut; for the plumb-cut, mark along the body of the square. The figure *13* on the square is to the octagonal roof what the figure *17* is to a rectangular roof.

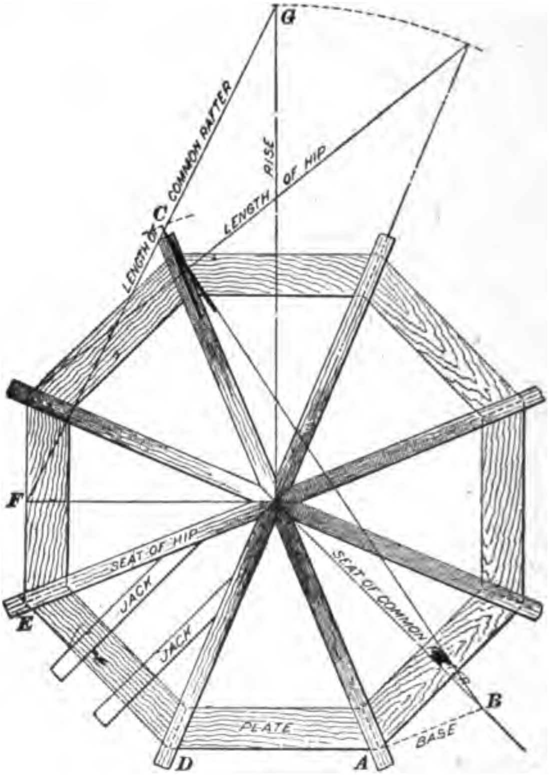

FIG. 49

81. Side Cut for Octagonal-Roof Hip Rafters. There are several ways of framing the tops of octagonal hips, and the side or cheek cut of the hip rafters will therefore depend on the method of framing. Figs. 49, 50, and 51 show three methods of framing. In Fig. 49, all hip rafters meet at a point; both sides of each rafter are cut off at an angle of 22½° in plan, and, if the rafters were laid level, this

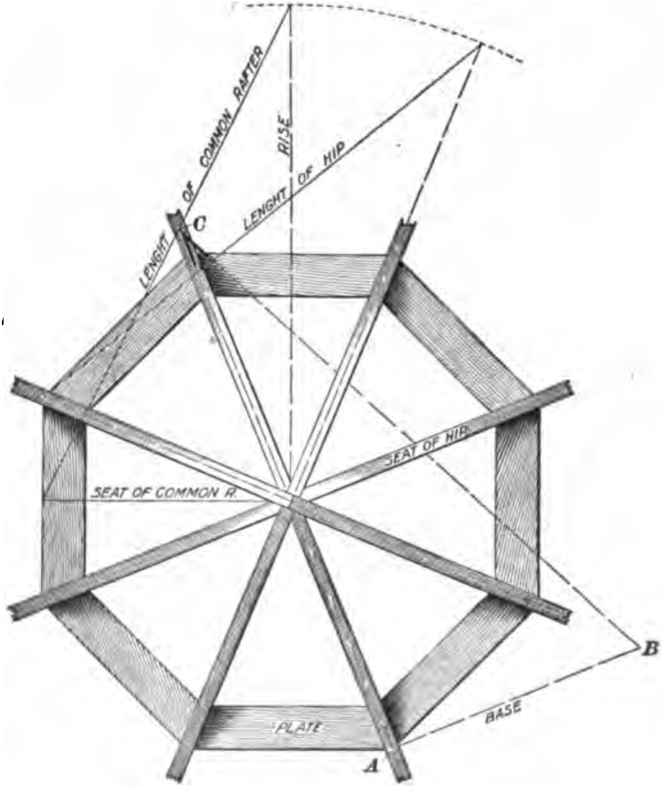

FIG. 50

would be the correct angle for the side cuts. As a matter of fact, however, the rafters are on a pitch; consequently, the side cut is less than 22½°, and as the roof gets steeper, the angle, or side cut, becomes more acute.

To find the figures to use on the square when the hips are framed in this manner, use the following method. Fig. 49

shows the plan of a hexagonal roof, with all the hip rafters in place. The rise and lengths of both the common rafter and the hip are shown. From the end of any of the hips, as at *A*, lay off a perpendicular to the seat of the hip, and continue this perpendicular until it intersects the seat of the common rafter produced at *B*. Then, from *A* on the seat of the hip produced, lay off the distance *A C* equal to the length of the hip. Connect *CB*; then, *A C B* will be the desired angle, or cheek bevel, to be used on both sides of the hip. The figures to use on the square are the distances *A B* on the tongue and *A C* on the body, cutting along the body. As *A B*, or the base, is a constant distance per foot of run, the following rule is deduced, which will hold true for all unbacked hips framed in this manner.

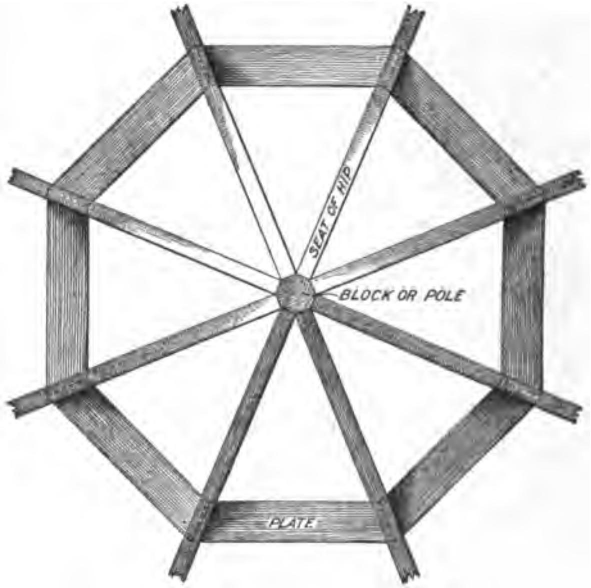

Fig. 51

Rule.—*For the cheek cut of hip rafters on octagonal roofs, take 5.38, or 5⅜, inches on the tongue of the square, and the length of the hip per foot of run on the body of the square, and cut along the body.*

When the hip is backed, take 4.97, or 5, inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.

82. In Fig. 50, two of the hip rafters butt against each other at their upper ends, and at right angles to them and butting against their sides are two other rafters; all four rafters have square cuts on the top. The other four rafters are framed into the angles of the first four, and have cheek cuts on both sides, the angle of cheek cut in the plan being 45°. The method of obtaining the true cheek cut is the same as explained in the preceding article, with the exception that in this case the base is carried to the seat of the hip produced. The figures to use on the square are found by taking the distance *A B*, or the base, on the tongue, and the distance *A C*, or the length of the hip, on the body, the body giving the cut.

The following rule will hold true for the side cut of the four jack-rafters, if unbacked, when framed in the manner described.

Rule.—*Take 13 inches on the tongue of the square and the length of the hip per foot of run on the body of the square, and cut along the body. When the hips are backed, take 5 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and mark along the body; then, apply the square, to this mark, using the same figures, and cut along the body.*

83. Fig. 51 shows a plan of an octagonal roof in which the hips are framed to an octagonal block, or pole, in the center. When rafters are framed in this manner, the only cut at the top is the plumb-cut.

84. **Octagonal-Roof Jack-Rafters.**—Fig. 52 shows a developed side of the roof illustrated in Fig. 51. To make this development, lay off *G F* equal in length to the common rafter; from *F* and at right angles, lay off *F D* and *F E*, each equal to one-half the length of one side of the octagon. Connect *G* and *D*, and *G* and *E*; then, these two lines will be the correct length of the hips, and the triangle EGD will be the true size and shape of one side. Furthermore, all the members of the roof will be shown in their true lengths, and the angles found will be the true angles.

For the side cut of the jack-rafters to fit against the hip, take the distance FD on the tongue of the square and the length of the common rafter FG on the body of the square, and cut along the body. For the side cut of any octagonal jack-rafter, take 5 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.

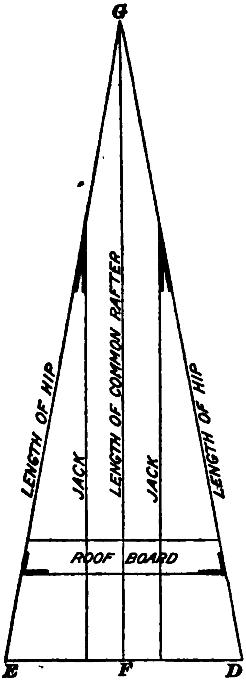

FIG. 52

The true length of the jack-rafter is shown in this illustration. To obtain the difference in lengths of jack-rafters in any octagonal roof, use the following proportion: 5, or 4.97, inches is to the length of the common rafter per foot as the spacing, in inches, is to the difference in length; or, multiply the length of the common rafter per foot of run by .201 and then by the spacing in inches. Thus, the length of the common rafter per foot of run in a 16-inch pitch is 20 inches. If jack-rafters are spaced 16 inches on centers, then the difference in the length will be in the first case, $4.97 : 20 = 16 : 64.4$; in the second case, $20 \times .201 \times 16 = 64.32$ inches. That is, the first jack-rafter next to the common rafter will be 64.32 inches shorter than the common rafter, the second jack-rafter will be 64.32 inches shorter than the first jack-rafter, and so on.

The cut of the roof boards to fit over the hips can be obtained by using the same figures as for the side cut of jack-rafters, but the cut must be made along the tongue of the square.

85. Backing Hips for Octagonal Roofs.—Fig. 53 shows two methods for obtaining the figures on a square to back the hip rafters on an octagonal roof. The method shown on the left side of the illustration is applicable to all hips, even when the bevel is not the same on both edges. Lay off the line *A C* equal to the rise of the rafter, and connect *B* and *C*. From any point on *B C*, as at *D*, erect a perpendicular to *B C*, intersecting the seat of hip in *E*. Through the point *E*, draw the line *J H* parallel with the pitch of the rafter; also, through *E* erect a perpendicular to the seat of the hip, intersecting the plate line, or the plate line produced. In this case, the perpendicular intersects the plate line at *G*. Make *E H* and *E J* each equal in length to *E G*. Connect *D* and *H*, and *D* and *J*; then, the angle *E D H* will be the proper bevel for one side of the hip, and the angle *E D J*, which in this case is equal to *E D H*, will be the proper bevel for the other side. The figures to use on the square are the distances *E H* on the body and *E D* on the tongue, cutting along the tongue.

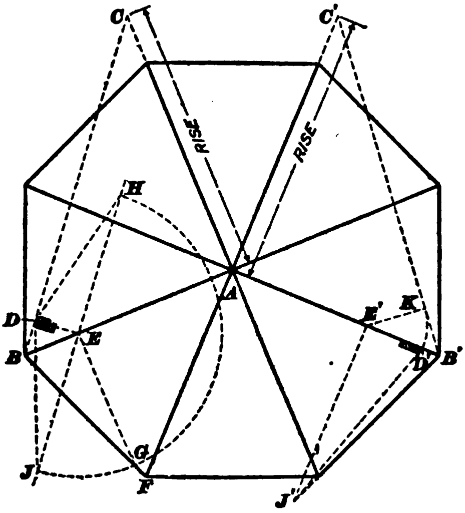

FIG. 53

86. The method shown on the right in Fig. 53 is applicable only when both sides of the rafter are backed with the same bevel. At *K*, on the pitch line *B' C'*, erect a perpendicular intersecting the seat of the hip *A B'* at *E'*. From *E'*, and at right angles to the seat of the hip, draw *E' J'*, intersecting the plate line produced. Connect *J'* and *D'*, and the angle *J'D'E'* will be the bevel. The figures on the square are the distances *E'D'* on the tongue and *E'J'* on the body. Cut along the body.

This method may be used for any regular polygon, while the first method can be used either for a regular or for an irregular plan.

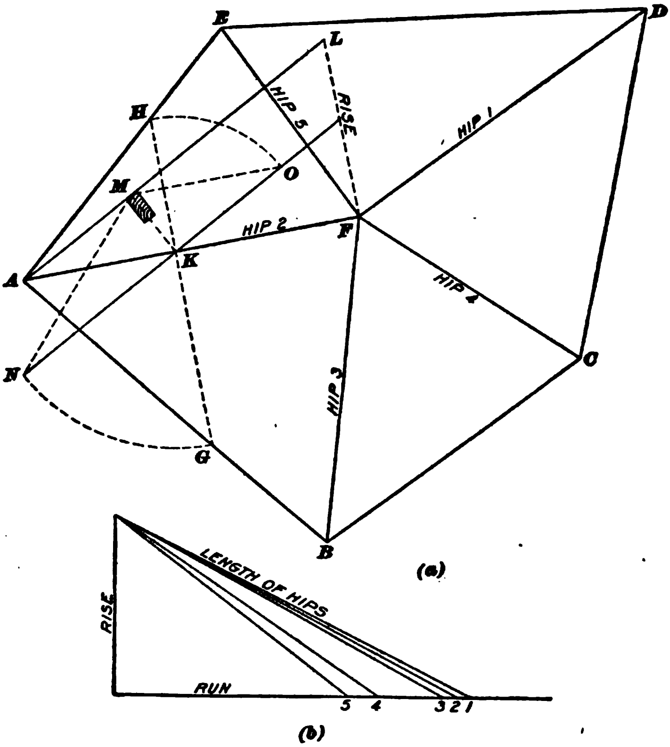

FIG. 54

87. The first method applied to an irregular plan is shown in Fig. 54 (*a*). *ABCDE* is the plan of a hip roof containing five hips, no two of which have equal lengths, but all of them have the same rise; consequently, no two of the roof surfaces have the same pitch.

To find the backing for both sides of hip *No. 2*, make *FL* equal to the rise, and connect *L* and *A*. From any point on the line *LA*, draw *MK* at right angles to *LA*, the point *K* being in the seat line *AF*. Through *K* and at right angles to *AF*, draw *GH*; also, through *K* and parallel with the pitch of the rafter *AL*, draw *NO*. Make *KO* equal in length to *KH*, and *KN* equal to *KG*.

Connect *M* and *O*, and *M* and *N*. The angle *KMO* is the bevel to apply on the side *H* of the rafter, and the angle *KMN* is the bevel to apply on the side *G*.

The figures to use on the square are the distances *MK* and *KO*, for the *H* side of the rafter, and *MK* and *KN* for the *G* side, *MK* giving the cut in both cases.

Incidentally, in (*b*) is shown a short method of finding the lengths of all the hips.

88. Purlins for Octagonal Towers.—The plan and elevation of an octagonal tower is shown in Fig. 55, the line *AB* representing the line of purlin. To find the bevels, draw the line *AC* at right angles to the pitch, or slant, of the side. Make *AD* equal to *EF*, and connect *D* to *C*. The angle shown at *D* will be the down cut of the purlin, and that shown at *G* will be the face cut. The figures on the square for bevel *D* are the length *AD* on the tongue and the length *AC* on the body, the tongue giving the bevel.

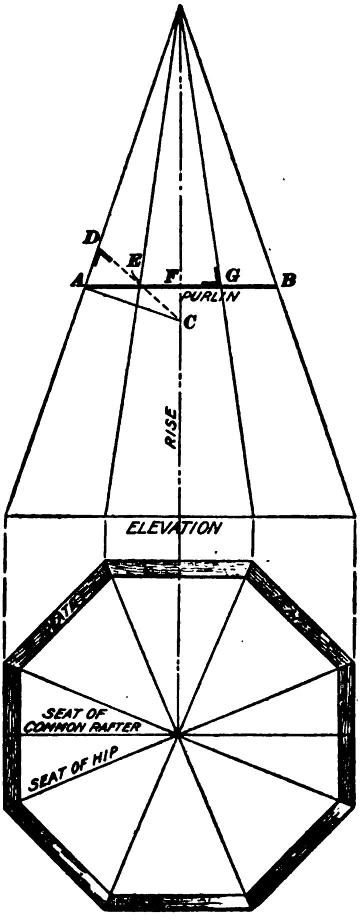

FIG. 55

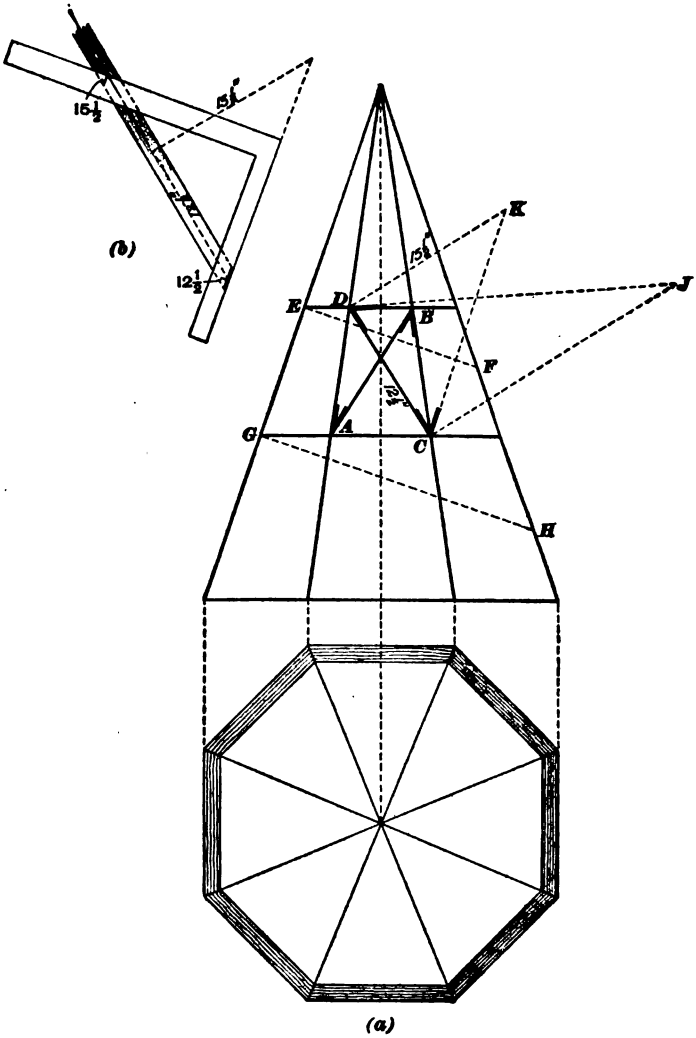

FIG. 56

89. Brace Bevels for Octagonal Towers.—The method of finding the brace bevels for an octagonal tower is similar to finding the same bevels of a square tower. Fig. 56 (*a*) shows the plan and elevation of an octagonal tower. The lines *A B* and *C D* represent the lines of braces. From *E*, draw the line *E F* at right angles to the pitch of the tower, and from *G* draw the line *G H* at right angles to the same side. Draw *D K* at right angles to the brace line *C D*, and make it equal in length to *E F*; connect *K* to *C*. From *C* and at right angles to the brace *C D*, draw *C J*, making it equal in length to *G H*; connect *J* to *D*. The bevels shown at *A* and *B* are to be applied to the side of the braces, and those shown at *D* and *C*, to the upper face, or back of the braces, *D* being applied to the upper and *C* to the lower end of the brace. It will be noticed that bevels *A* and *B* are in the angles between the brace line *A B* and the two hips.

In (*b*) is shown how to apply the square to obtain the cut for the bevel at *C*.

90. Framing Hexagonal Roofs.—In Fig. 57 are shown the plan lines of a hexagonal roof or tower. The method of finding the figures on the square to obtain the lengths and cuts of rafters is the same as that for framing octagonal roofs. The figures on square *No. 1* indicate that the common rafters rise 20 inches per foot of run. By placing square *No. 2* on the seat of the hip, with its heel on the line of the body of square *No. 1*, the figures on square *No. 2* giving the pitch of the hip rafter will be found to be 13⅞ inches on the tongue for the run, and 20 inches on the body for the rise. The cuts will be found by marking along the tongue for the foot-cut and along the body for the plumb-cut. The length will be found by stepping along the timber the number of times that the common rafter contains feet in its run.

The common rafter in a hexagonal roof is the same as in an ordinary roof. The figures *13⅞* are to the hexagonal hip what *13* is to the octagonal hip or *17* is to the rectangular hip.

The method of finding purlin and brace bevels is the same in the hexagonal roof as in the octagonal roof.

91. Side Cuts of Hexagonal Hips.—The method of finding the side cuts for hexagonal hips is the same as for octagonal hips. There are a number of ways of framing the top ends of the hips, but as the method of finding the figures to use on the square is the same as for octagonal hips, the expressions on the square will be given without a demonstration of the principle.

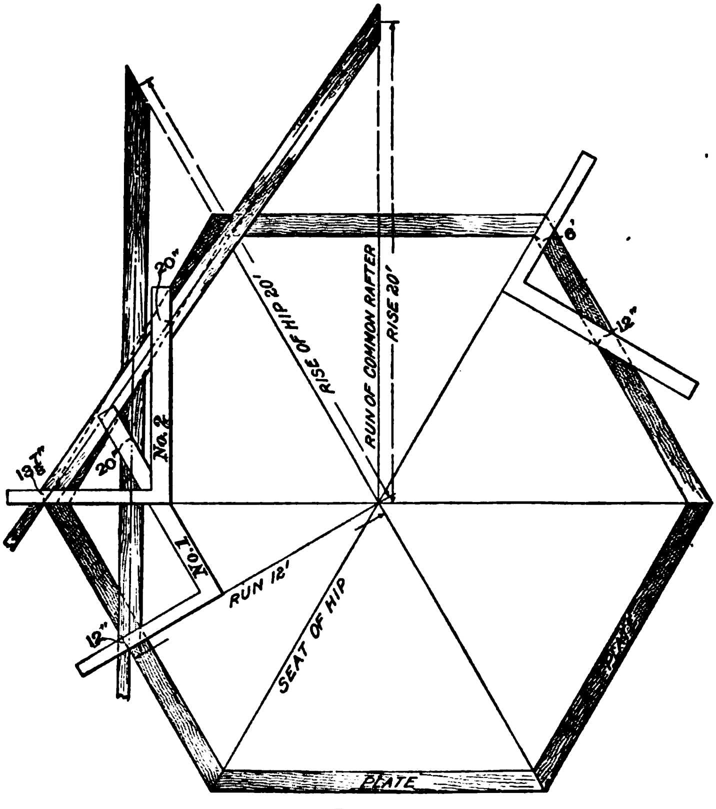

FIG. 57

Fig. 58 shows four ways of bringing the tops of the hips together. In (*a*) all the hips are framed to a point, and the side cuts are the same on both sides of the six rafters. The figures to use on the square to obtain these bevels are 8 inches on the tongue, and the length of hip per foot of run on the body. Cut along the body. If the hips are backed, take 6.92, or $6\frac{15}{16}$, inches on the tongue of the square, and the length of the common rafters per foot of run on the body, and cut along the body.

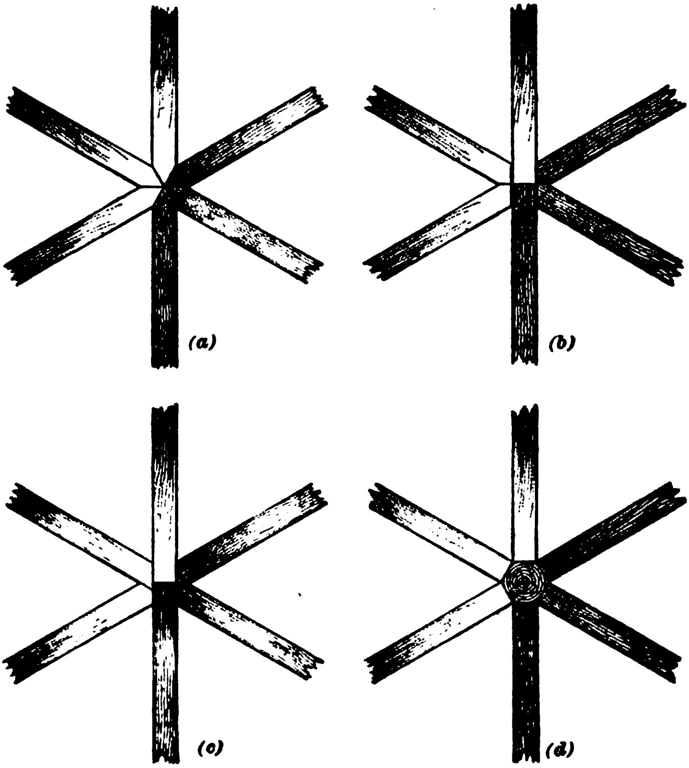

Fig. 58

92. If the hips are framed as in Fig. 58 (*b*), two of the hips will butt against each other and the only cut will be the plumb-cut. The cuts for the other four hips are similar to each other. They have a cheek cut on both sides, but these cuts are not the same. The cheek cut on the side that fits against the butting hip is found by taking 12 inches on the tongue of the square and one-half the length of the hip per foot of run on the body of the square, and cutting along the body. The cut for the other side of the hip is the same as when the hips meet at a point, that is, 8 inches on the tongue of the square, and the length of the hip per foot of run on the body of the square. In this case, the cut is along the body. If the hips are backed, take 6.92 inches on the tongue and the length of the common rafter per foot of run on the body, and mark along the body; then, apply the square to this mark, using the same figures as before, and cut along the body for the side to fit against the butting hip. For the other side, take 6.92 inches on the tongue and the length of the common rafter per foot of run on the body of the square, and cut along the body.

93. If the hips are framed as in Fig. 58 (*c*), two of the hips butt against each other as in (*b*). The other four hips have the same cuts; two of them have the cut from one side only, and the other two have the same cut on both sides. This latter cut is the same as for the side cut of the hip to fit against the butting hip in (*b*), that is, 12 inches on the tongue of the square and one-half the length of the hip per foot of run, on the body of the square. The cut is along the body. When the hips are backed, the side cut is 6.92 inches on the tongue, and the length of the common rafter per foot of run on the body. The cut is along the body. Apply this cut to each side of the two rafters, and to one side only of the other two rafters.

94. In Fig. 58 (*d*) is shown the hip framed to a center pole or block. In this case, there are no cheek cuts, the plumb-cut only being applied.

95. Jack-Rafters and Roof Boards for Hexagonal Roofs.—The method of finding the figures on a square for the side cuts of jack-rafters in hexagonal roofs is the same as that used for finding the cheek cuts for jack-rafters in octagonal roofs, as already explained. The rule that holds true for all hexagonal roofs, regardless of pitch, is as follows:

Rule.—*To find the cheek cut for a jack-rafter on a hexagonal roof, take 6.92 inches on the tongue of the square and the length of the common rafter per foot of run on the body of the square, and cut along the body.*

For the roof boards, use the same figures on the square, but cut along the tongue.

The difference in lengths of jack-rafters in hexagonal roofs, is expressed by the following proportion: 6.92 is to the length of the common rafter per foot of run as the spacing, in inches, is to the difference in length. For example, take a roof with a pitch of 16 inches in 12 inches, in which the jack-rafters are spaced 16 inches on centers. For this pitch, the length of the common rafter is 20 inches per foot of run. Then, 6.92 inches : 20 inches = 16 inches : 46.24 inches; or, $\frac{20 \times 16}{6.92} = 46.24$ inches, which is the difference in length. The difference may also be found by multiplying the length of the common rafter per foot of run, by .144 and by the spacing in inches; thus, in the preceding case, $20 \times .144 \times 16 = 46.08$ inches.

Set a bevel instrument at 6.92 inches on the tongue of the square and 20 inches on the body. Slide the instrument to 5.59 inches on the tongue, and the body will read, 16.15, which, subtracted from 20 feet, leaves 3.85 feet, or 3 feet 10.2 inches, or 46.2 inches. The 5.59 is obtained by subtracting 16 inches, or 1.33 feet, from 6.92. If the common rafter is 20 feet long, then the jack-rafter next to the common rafter will be 16.15 feet, or 16 feet 1.8 inches, long.

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Note.—All items in this index refer first to the section (see the Preface) and then to the page of the section. Thus, "American holly, §31, p42," means that American holly will be found on page 42 of section 31.

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